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Combining multiple trips in a port environment for empty movements minimization

Claudia Caballini [a,b,*], Ilaria Rebecchi [a], Simona Sacone [a,b]

[a] *DIBRIS-Department of Informatics, BioEngineering, Robotics and Systems Engineering. University of Genova, Via Opera Pia 13, Genoa, 16145, Italy*

[b] *CIELI-Italian Centre of Excellence in Integrated Logistics. University of Genova, Piazza della Nunziata 6, Genoa, 16124, Italy*

Abstract

Road transportation represents the most used transportation mode to cover short distances. However, structural lack of planning and optimization in road transportation creates negative effects both for companies and for the social community, such as environmental pollution, economic loss and road congestion. These effects are mainly due to the fact that a lack of planning can yield the necessity of a huge number of empty trips. Usually trucks that pick up or deliver a full container in a port must return back the empty container to the place where the trip started, so performing one leg of the total trip without payload. The aim of the present paper is to propose a mathematical approach for combining multiple trips in a port environment (specifically, import, export and inland trips) by considering the opportunity of carrying two 20 ft containers simultaneously on the same truck and by using the same load unit if possible. In this way, in the same route, more than two nodes can be visited with the same vehicle thus significantly reducing the number of total empty movements. Time windows constraints related to companies and terminal opening hours as well as to ship departures are considered in the problem formulation. Moreover driving hours restrictions and trips deadlines are taken into account, together with goods compatibility for matching different trips. An experimental campaign based on real data is discussed in the paper.

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Keywords: Trips combination; Optimization; MILP; import-export road trips; empty movements.

1. Introduction

One of the worst consequences of the lack of planning in road transportation is the huge number of empty truck trips, whose negative externalities affect both companies and the social community. So, empty movements must be reduced and trucks utilization has to be maximized. This can be done by a proper optimization of trips and empty containers repositioning. The trips taken into account in the present work are of three types: they may originate or end in the port (import and export trips, respectively) or they may be executed in the inland (inland trips). Full containers,

* Corresponding author. Tel.: +39-328-7264867 ; fax: +39-019-21945136.
E-mail address: claudia.caballini@unige.it

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whatever origin or destination they may have, are picked up in certain points of the network (ports, companies or inland depots) and must usually return empty to the origin of their trip for further use: this implies that one leg of the trip is performed without payload, in a not optimized way.

In the literature, some studies focusing on the problem of combining import and export trips can be found. For instance, Zhang et al. (2010) proposed a heuristic approach for determining pick up and deliver sequences for daily operations with the goal of minimizing transportation costs, while Vidovic et al. (2012) solved the problem when pick up and deliver nodes may be visited only during predefined time intervals. Lately the problem was studied by Nguyen et al. (2013), who provided a tabu search meta heuristic for time dependent and multi zone multi trip vehicle routing problem with time windows. Other meta-heuristics were proposed by Sterzik et al. (2013) where the total operating time of all trucks is minimized respecting given hard constraints, and by Ayadi et al. (2013) where the trips combination problem is solved with a local search procedure. In both these works, EU driving time regulations are not taken into account. Instead, Derigs et al. (2011) presented two heuristic approaches for solving a real world vehicle routing problem for air cargo road feeder services on which driving hours constraints are strictly considered to combine multiple trips with the same tractor. Driving hours and traffic congestion have been taken into account also by Kok et al. (2011), who proposed an integer linear problem formulation that minimizes total duty time; Goel (2010) studied the problem of scheduling working hours of team rivers in European road freight transport where a sequence of locations must be visited within given time window and solved the problem applying a depth-first-breadth-second search method which can find a feasible schedule complying with standard daily driving time limits. Caballini et al. (2014) proposed an optimization approach devoted to combine trips two by two in a cooperative environment among different carriers, but without taking into account driving regulations. The majority of works in the literature focuses on 40-foot containers while, Schnberger et al. (2013) and Funke et al. (2014) 's works consider the transportation of 20-foot and 40-foot containers, with trucks being able to transport up to two 20-foot or one 40-foot container. This extension of the basic 40-foot problem increase the complexity of the problem dramatically and it is solved by a mixed integer linear program formulation. Moving from this scenario, the aim of the present paper is to propose a mathematical approach for combining multiple trips, considering the opportunity of carrying two 20 ft containers simultaneously on the same truck with a trailer and using the same load unit if allowed. The innovation from previous work stands in the fact that, in the same route, more than two nodes can be visited, by combining up to three trips. This significantly reduces the total number of empty movements, while respecting time windows constraints as well as EU-driving hours regulation. Moreover, for what concerns the export cycle, ships' scheduled departures are also taken into account as soft time constraints. The model runs in a daily basis, in the context of tactical/operative planning and truck operators own the problem of trips combination.

The paper is organized as follows. In section 2 the problem under analysis is described; in section 3 the mathematical formulation for combining trips three by three is presented, while in section 4 the results obtained by applying the proposed model to a real case study are analyzed, discussed and compared with the cases of only two trips combination or without any combination. Finally, in section 5 some conclusions are drawn together with further research ideas.

2. Problem description

Dealing with the objective of maximizing truck utilization, this paper tries to combine three kinds of trips: import, export and inland ones. Fig. 1 provides a framework of the type of road links involved in each kind of trip. In this work, it is assumed that a single trip is performed as a "round-trip", meaning with this term a trip in which the hauler has to go back and forth between two nodes performing one leg of the trip with an empty container or without any payload: this kind of trips is often utilized because, in an environment where freight forwarders and shipping companies compete for transporting cargo in the inland, the latter, which usually own empty containers, require to bring them back to the same location where they have been picked up.

As shown in Fig. 1, in the import cycle, the truck carrier has to carry out the following activities:

- pick up a full container in the port;
- travel with the full container to the inland company where it is stripped (link port-A in Fig. 1);

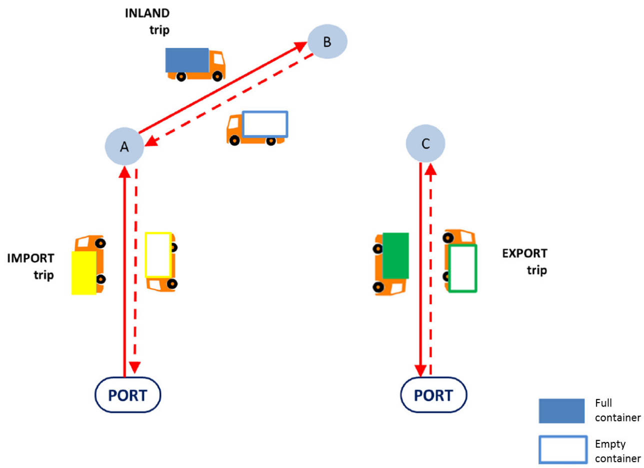

Fig. 1. Round trip sketches: import, export and inland cases.

- bring back the empty container to the port or to a depot of empty containers pointed out by the shipping company usually located near the port (link A-port in Fig. 1).

For the export cycle the carrier must:

- pick up an empty container in a depot located near the port;
- travel with the empty container to the exporter company where it is stuffed (link port-C in Fig. 1);
- travel back to the port with the full container where it can be released and embarked on the ship (link C - port in Fig. 1).

Finally, for what concerns the inland trip, the carrier has to:

- pick up a full/empty container from a company/inland depot;
- travel with the full/empty container from its origin to its destination in the inland (link A-B in Fig. 1);port
- bring back the empty/full container to its origin (link B-A in Fig. 1).

As the execution of these kinds of trips generates a lack of efficiency, the goal of this work is to optimize transportation operations by combining three trips in the same route. This allows to use only one truck and to dramatically reduce the number of kilometers performed by vehicles without payload.

Trips combination can be pursued if they are compatible in terms of type of goods transported in case the same load unit is re-used, if there is any overlapping in the times of delivery/pick up and if there is sufficient time between successive trips to allow the necessary loading/unloading operations. In order to give more insight into the problem under consideration, let us consider, as showed in Fig. 2, the case in which an operator has to serve the demand of:

- a set of import trips from a port to some companies located in a certain metropolitan area in the port hinterland (port-A);
- a set of inland trips in the inland area or within a given distance from it (A-B);
- a set of export trips from companies located in the inland area to the port (C-port).

Fig. 2 highlights the links performed with full containers in case of three, two and no trips combination. If trips are performed singularly, each of them will generate an empty movement and three trucks are required (Fig. 1). So, an example of combination of three trips takes place according to the following steps will be(Fig. 3):

- the truck picks up two 20 ft containers in the port, a full container (a') for the import cycle and an empty container (b') for the export one;
- the truck travels to the first importer company and strips the container (a') in node A ;
- if an inland trip is compatible with the import trip, the same container (a") is stuffed for the inland trip;
- the truck travels with the empty export container (b') and the inland full one (a") to a second company located in B where it is stripped;
- the truck travels with the two empty containers (a"', b') to the exporter company in node C where the export empty container is loaded (b"). Note that this is a repositioning trip and it could be needed also between the import and the inland trips;
- the truck travels with the full export container (b") and the empty import one (a"') to the port where the former will continue its journey by ship and the latter is left in the port depot where started its trip.

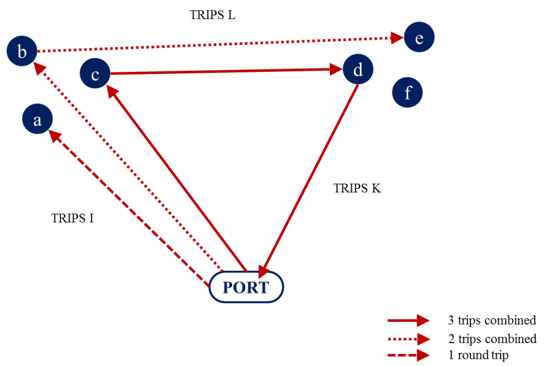

Fig. 2. Example of 1,2,3 trips combined.

Note that many other configurations can be tested and solved in combining import, export and inland trips, in terms of trips order and type of containers (full or empty) carried out in each link.

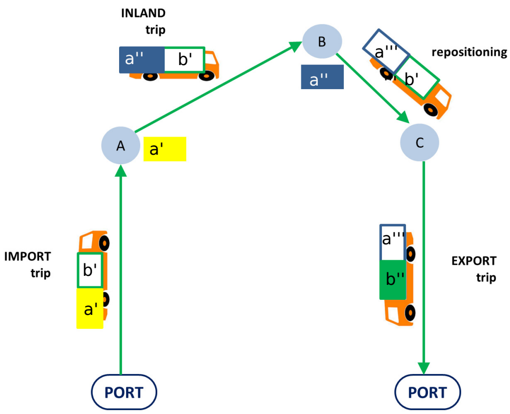

Fig. 3. Framework of a three trips combination.

For the convenience of the combined trip, the distance covered by the sum of the links must be lower than the sum of the links performed singularly as round trips.

Moreover, a certain number of assumptions has been made:

- all companies are equipped with handling means in order to unload and load containers from/to trucks, if necessary;

- time windows of trips are known in advance and do not vary dynamically;
- as the model is set, the deadline of the first trip is always respected;
- the considered costs are the following: transport costs (which depend on the distance travelled), delay costs (if the deadline is not respected), cost of night detention in the port and cost of change of vessel if the export container arrives later with respect to the port terminal deadline.

The regulation of driving hours severely restricts the set of feasible combinations of trips. In fact, the law imposes daily restrictions on driving time, which must not overcome 9 hours per day. Once reached this limit, the driver must take a rest periods of 11 hours. Moreover, driving time between two breaks has not to exceed 4.5 hours, after which, the driver must take a break period of 45 minutes. All of these restrictions have been considered in the present problem formulation.

3. Problem Statement

Given a certain set of import, export and inland trips, the mathematical model here proposed allows to match them three by three so as to minimize the total cost and the total number of trucks needed.

The network is represented as a graph $G = (V, A)$, where V represents the set of nodes and A the set of links. Nodes are the points of origin and destination of trips corresponding to companies, ports and inland depots, while links are the shortest paths that connect nodes. It is assumed that any node may have simultaneously both containers demand and supply requests. Transportation demand is set as the number of containers to be transported. Trips are not compatible if, for instance, a dirty commodity is firstly carried in a container which is later used in another trip for transporting ”cleaner” freight.

Moreover, in the present work, the following soft time constraints are considered:

- deadlines of import, export and inland trips;
- opening and closing time of port terminals, companies and depots.

Finally, a crucial constraint is represented by vessel departure time, that may generate two different scenarios:

- if the final travel time of the combined trips exceeds the departure time but is lower than the terminal closing time, only the ”change of vessel” cost has to be paid (in fact, the container departure has to be replanned on the next ship);
- if the final travel time also exceeds the terminal deadline, the night detention cost has to be paid in addition to the ”change of vessel cost”.

For modeling purposes, let us use the following notation:

- T is the set of trip indexes;
- S is the total time availability of the truck;
- d_i, $i \in T$, is the travel distance to cover trip i. It is measured in kilometers;
- t_i, $i \in T$, is the travel time spent for trip i and is function of the distance and the average speed of a truck. Measured in hours;
- s is the service time taken on each customer/terminal node to load/download goods. It is measured in hours;
- c_u is the kilometer unit cost which takes into account both fixed and variables costs;
- C_i, $i \in T$, is the cost of serving trip i singularly;
- C_{ilk}, $i, l, k \in T$, is the cost of serving the triple combination of trips i, l and k;
- C^d_{il}, $i, l \in T$, and C^d_{lk}, $l, k \in T$, are the delay costs for performing the combination of trips (i, l) and (l, k) respectively;
- c_d is the unit cost of delay;
- ϵ_{il} and ϵ_{lk} are the distances needed for repositioning the container from a node to another one if the destination node of the first trip (i or l) and the origin node of the second one (l or k) do not coincide;

- m_{ilk},$i, l, k \in T$, is a binary parameter that assumes value equal to 1 if the container used in trip i can be reused for trips l or/and k;
- q_i, $i \in T$, is the starting time of trip i;
- h_i, $i \in T$,is the deadline for trip i;
- f_i, $i \in T$, is the finishing time of trip i which coincides with its deadline h_i only for the first trip;
- q_{il}, $i, l \in T$, is the starting time of trip l after having executed trip i and after an eventual repositioning link, $q_{il} = f_i + \epsilon_{il} + s$;
- f_{il}, $i, l \in T$, is the finishing time of trip l when combined with trip i and is given by $f_{il} = q_{il} + t_l + s$;
- q_{ilk}, $i, l, k \in T$, is the starting time of trip k when combined with trip i and l and is given by $q_{ilk} = f_{il} + \epsilon_{lk}$;
- f_{ilk}, $i, l, k \in T$, is the finishing time of trip k when combined with trip i and l and is given by $f_{ilk} = q_{ilk} + d_k + s$;
- t_{ilk} is the total time required for trips combination. It is given by $t_{ilk} = f_{ilk} + s$. It is measured in minutes and hours;
- P_i^O, $P_i^{\hat{O}}$, $i \in T$, are respectively the opening and closing time of the origin node of trip i;
- P_i^D, $P_i^{\hat{D}}$,$i \in T$, are respectively the opening and closing time of the destination node of trip i;
- v_{ilk} is a binary parameter associated with the vessel change if the container cannot reach the port terminal on time. This variable is equal to 1 if $f_{ilk} > h_k$. A cost of change of vessel is associated to this parameter;
- n_{ilk} is a binary parameter that assumes value equal to 1 if the combination of trips i, l, k ends after the closing time of the port terminal: in this case the truck has to wait until the opening time of the terminal in the next day and, so, a night detention cost is paid.

The optimization problem has two sets of decision variables. The first one is represented by binary variables y_{ilk}, $i, l, k \in T$, which assume value equal to 1 if trips i, l, k are matched together in the same route and 0 otherwise. The second set of decision variables is represented by x_i, $i \in T$, assuming value equal to 1 if trip i is not combined, and 0 otherwise. This set of variables is introduced in order to include trips that are not combined in the computation of the total cost. It holds:

$$x_i = 1 - \sum_{i \in T} \sum_{l \in T} \sum_{k \in T} y_{ilk} \quad i \in T \tag{1}$$

The objective is to minimize the total cost in executing all the trips by combining them three by three. The cost for performing the triple of trips (i, l, k) is given by (3).

$$C_{ilk} = m_{ilk}[c_u(d_i + d_l + d_k + \epsilon_{il} + \epsilon_{lk}) + C_{il}^d + C_{lk}^d + C_v^d + C_n^d] \tag{2}$$

being $C_v^d = 30v_{ilk}$ and $C_n^d = 320n_{ilk}$.

$$C_i = 2c_u d_i \tag{3}$$

The problem statement follows.
Problem

$$minU = \sum_{i \in T} \sum_{l \in T} \sum_{k \in T} C_{ilk} y_{ilk} + \sum_{i \in T} C_i x_i \tag{4}$$

subject to (1) *and to:*

$$\sum_{i \in T} \sum_{l \in T} y_{ilk} \leq 1 \qquad k \in T \tag{5}$$

$$\sum_{i \in T} \sum_{k \in T} y_{ilk} \leq 1 \qquad l \in T \tag{6}$$

$$\sum_{k \in T} \sum_{l \in T} y_{ilk} \leq 1 \qquad i \in T \tag{7}$$

$$t_{ilk} y_{ilk} \leq S \qquad\qquad i, l, k \in T \tag{8}$$

$$q_{ilk}y_{ilk} + M(1 - y_{ilk}) \geq f_{il} + \epsilon_{lk} \qquad i, l, k \in T \tag{9}$$

$$q_{il}y_{ilk} + M(1 - y_{ilk}) \geq f_i + \epsilon_{il} \qquad i, l, k \in T \tag{10}$$

$$0 \leq (f_{ilk} - P_k^D)y_{ilk} \leq P_k^{\hat{D}} y_{ilk} \qquad i, l, k \in T \tag{11}$$

$$0 \leq [(f_{ilk} - t_{ilk}) - P_k^O]y_{ilk} \leq P_k^{\hat{O}} y_{ilk} \qquad i, l, k \in T \tag{12}$$

$$0 \leq (f_{il} - P_l^D)y_{ilk} \leq P_l^{\hat{D}} y_{ilk} \qquad i, l, k \in T \tag{13}$$

$$0 \leq [(f_{il} - t_{il}) - P_l^O]y_{ilk} \leq P_l^{\hat{O}} y_{ilk} \qquad i, l, k \in T \tag{14}$$

$$0 \leq (t_i - 0.75)y_{ilk} \leq 4.5 \qquad i, l, k \in T \tag{15}$$

$$0 \leq (\epsilon_{il} - 0.75)y_{ilk} \leq 4.5 \qquad i, l, k \in T \tag{16}$$

$$0 \leq (\epsilon_{lk} - 0.75)y_{ilk} \leq 4.5 \qquad i, l, k \in T \tag{17}$$

$$y_{ilk} \in (0, 1) \qquad i, l, k \in T \tag{18}$$

$$x_i \in (0, 1) \qquad i, l, k \in T \tag{19}$$

□

where $t_i = \frac{d_i}{v}$, $t_l = \frac{d_l}{v}$, $t_k = \frac{d_k}{v}$, $t_{il} = \frac{d_i+d_l}{v}$, $t_{lk} = \frac{d_l+d_k}{v}$.

Constraints (5) ensure that each trip k can be combined at most once with trips i and l; similarly for trips l and trips i respectively in constraints (6) and (7). Constraints (8) impose that the time required by a truck for performing the combination is not exceeding the total time availability of the truck, supposed equal to the driver's total driving time. Constraints (9) and (10) yield the respect of timing of trips: trips i must be performed before trips l , and trips k at the end. Constraints from (11) to (14) are related to company and terminals time windows. The respecting of EU regulation of driving hours is guaranteed by constraints from (15) to (17), where each distance traveled, less the break of 45 minutes, must be lower than 4,5 hours of driving. Finally, constraints (18) and (19) define the nature of the decision variables of the problem.

4. Results analysis and comparisons

The model described in section 3 has been implemented in MPL by using Cplex as MILP solver on a laptop having the following features: Intel(R) Core(TM) i5 CPU M 430, @2.27 GHz, memory (RAM) 4 GB.

In order to test the efficacy of the proposed approach, an experimental campaign has been carried out on, based on real data regarding the import, export and inland trips between the port of Genoa in Italy and the inland area of Milan.

In Table 1 the input data related to one of the real instances tested are shown. Each trip is characterized by a typology (import, inland or export), an origin, a destination, the shortest distance to be traveled, the index of criticism of the goods transported, the trip deadline and the vessel departure time for export trips. Note that a criticality index equal to 1 means that goods transported are toxic and the container can not be reused unless a specific treatment is made; if its value is 2, goods transported dirty the container, so making it reusable only in some cases, while if its value is 3, it means that it can be reused without any treatment. So, Fig. 4 highlights the allowable combinations for

		Third trip								
		1			2			3		
	Second Trip	1	2	3	1	2	3	1	2	3
First Trip	1	N	N	N	N	N	N	N	N	N
	2	N	**Y**	N	N	**Y**	N	N	N	N
	3	N	**Y**	**Y**	N	**Y**	**Y**	N	N	**Y**

Fig. 4. Compatibility Matrix.

Table 1. Data related to trips.

Trip typology	Trip number	O	D	Distance	Criticality Index	Trip deadline	Vessel Dep. Time
Import	1	port	a	104	2	16	-
Import	2	port	b	102	1	11	-
Inland	3	a	b	14	3	12	-
Export	4	b	port	102	3	18	22
Inland	5	c	d	20	3	12	-
Export	6	d	port	126	3	19	22
Import	7	port	e	128	3	11	-
Import	8	port	c	121	3	11	-
Inland	9	e	c	12	3	13	-
Export	10	e	p	128	3	19	21
Inland	11	a	e	20	3	16	-
Inland	12	a	d	25	2	14	-
Export	13	d	port	126	2	19	22
Import	14	port	b	102	3	12	-
Inland	15	c	b	30	2	13	-
Inland	16	a	e	20	2	11	-
Import	17	port	e	128	2	10	-
Inland	18	b	e	15	2	16	-
Export	19	e	port	128	2	18	20
Export	20	a	port	104	2	18	20
Import	21	port	b	102	2	12	-
Inland	22	b	a	14	1	13	-
Inland	23	b	c	30	1	13	-
Export	24	b	port	102	2	17	22
Import	25	port	d	126	1	11	-
Export	26	d	port	126	1	14	18
Inland	27	b	e	15	2	13	-
Inland	28	b	d	10	3	15	-
Inland	29	b	c	30	3	10	-
Inland	30	e	c	15	3	16	-
Inland	31	c	b	30	3	15	-

Table 2. Data related to network nodes.

Node	Opening time	Closing time	Type of node
a	7 a.m.	3 p.m.	company
b	8 a.m.	4 p.m.	company
c	9 a.m.	4 p.m.	company
d	8 a.m.	4 p.m.	company
e	6 a.m.	10 p.m.	company
port	6 a.m.	4 p.m.	port terminal

the reuse of the same containers. Goods can be combined only if having the following combinations related to trips (i,l,k):(3-3-3);(3-3-2);(3-3-1);(3-2-2);(3-2-1);(2-2-2);(2-2-1).

In Table 2 data related to companies and port terminals opening and closing times are provided.

In order to calculate repositioning kilometers, and consequently their costs, an O-D matrix has been elaborated. Besides, the average truck speed has been set equal to 60 km/h for all the trucks and the unitary delay cost c_d has been set equal to 15 $euro/h$.

Results obtained over a total of 31 trips are shown in table 3 in which they are also compared with a 2 trips combination and the single round trip. It can be noted that total costs are definitely the lowest in the triple combination case and they increase up to the single trip execution. A benefit is obtained also for what concerns the number of trucks needed for performing the total trip demand: only 11 in the case of combining three trips and up to 31 when trips are performed singularly. Note that the number of trips combined for the different type (import, export, inland) are not balanced as happens in reality.

Table 3. Results obtained in case of three, two and single trip combination.

3 trips combined	**3 trips cost €**	**2 trips combined**	**2 trips cost (€)**	**1 trip**	**1 trip cost (€)**
1-20-22	222	1-18	119	1	104
2-18-29	147	2-30	117	2	102
3-16-24	165	3-31	44	3	14
4-17-31	260	4-29	234	4	102
5-13-30	161	5-28	30	5	20
6-21-27	243	6-26	354	6	126
7-12-26	299	7-20	245	7	128
8-15-23	181	8-24	235	8	121
10-14-28	240	9-21	114	9	12
11-19-25	274	10-27	143	10	128
9	24	11-19	148	11	20
–	–	12-25	151	12	25
–	–	13-17	254	13	126
–	–	14-16	132	14	102
–	–	15-23	60	15	30
–	–	22	28	16	20
–	–	–	–	17	128
–	–	–	–	18	15
–	–	–	–	19	128
–	–	–	–	20	104
–	–	–	–	21	102
–	–	–	–	22	14
–	–	–	–	23	30
–	–	–	–	24	102
–	–	–	–	25	126
–	–	–	–	26	126
–	–	–	–	27	15
–	–	–	–	28	10
–	–	–	–	29	30
–	–	–	–	30	15
–	–	–	–	31	30
11 trucks	2216 €	16 trucks	2408 €	31 trucks	4310 €

For testing the computational efficiency seven types of instances have been tested considering 19,25,30,37,60, 77 and 90 trips respectively. Table 4 shows the results obtained: the time needed to compute the solution is very low and reaches nearly 3 minutes only in case three trips are combined over a total number of 90 trips which is definitely a very high number for trips performed on a daily basis in a specific area. This computational time is more than acceptable for an off-line planning as the one it is here proposed. Moreover, Table 4 shows objective function values, CPU times, number of trucks used and percentage of trucks saved in two cases: when combining three trips with respect to two or to one, respectively (last two columns of Table 4).

5. Conclusions

In this paper an optimization model dealing with the combination of multiple road trips in a port environment has been proposed. More specifically, three kinds of trips (import, inland and export) have been considered with the goal of minimizing total costs. This can be achieved also by exploiting the possibility of using the same load unit in different trips, if necessary. A certain number of constraints have been taken into account such as time windows on nodes, goods compatibility, driving hours and trips deadlines. The results obtained on the real data campaign have shown that the approach demonstrated to be effective from two points of view: the minimization of total cost, in

Table 4. Comparisons among 3 trips combination - 2 trips combination - no combination.

Comb. Type	Trips ♯	Obj. func.	CPU time (sec)	Trucks ♯	% trucks saved from 2 trips	% trucks saved from 1 trip
3 trips	19	1835	1.20	7	-36.00 %	-63.00 %
	25	1975	12.00	9	-40.00 %	-64.00 %
	30	2457	12.60	12	-25.00 %	-60.00 %
	37	3552	18.60	15	-38.00 %	-59.00 %
	60	5489	27.00	24	-23.00 %	-60.00 %
	77	6939	117.0	27	-45.00 %	-65.00 %
	90	7548	202.8	36	-22.00 %	-60.00 %
2 trips	19	1884	5.40	11	–	-42.00 %
	25	2556	12.00	15	–	-40.00 %
	30	2852	12.60	16	–	-47.00 %
	37	3739	13.80	24	–	-35.00 %
	60	5697	30.00	31	–	-48.00 %
	77	7123	45.60	49	–	-36.00 %
	90	7712	77.40	46	–	-49.00 %
1 trip	19	3010	0	19	–	–
	25	4064	0	25	–	–
	30	4914	0	30	–	–
	37	6082	0	37	–	–
	60	10418	0	60	–	–
	77	13216	0	77	–	–
	90	15166	0	90	–	–

comparison with the two trips combination, or even better with no combination, by reducing the kilometers traveled with empty containers or without payload and the maximization of trucks utilization because a significant lower number of truck is needed to perform the whole trip demand. Moreover, also from a computational standpoint the presented methodology proved to be satisfying.

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