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WA1: Maritime Transportation I

Chair: Agostinho Agra,

Wednesday 10:30-12:30, Room: 6.2.53

A Multi-Product Maritime Inventory Routing Problem with Undedicated Compartments

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Keywords: inventory routing, maritime transportation, routing and scheduling, multiple products and undedicated compartment

Abstract

This paper considers the problem of routing bulk tankers to minimize cost while managing the inventory in ports. Multiple non-mixable products are transported and the allocation of products to undedicated compartments onboard the ships is an important aspect of the problem. An arc-flow formulation of the problem is proposed together with several valid inequalities. Computational results are reported for the model and two simplified models where either the compartments are dedicated or the products are mixable.

A MIP-Based Local Search Heuristic for a Stochastic Maritime Inventory Routing Problem

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Keywords: maritime transportation, vehicle routing, inventory routing, stochastic programming, matheuristic

Abstract

We consider a single-product maritime inventory routing problem in which the production and consumption rates are constant over the planning horizon. The problem involves a heterogeneous fleet of ships and multiple production and consumption ports with limited storage capacity. In spite of being one of the most common ways to transport goods, maritime transportation is characterized by high levels of uncertainty. The principal source of uncertainty is the weather conditions, since they have a great influence on sailing times. The travel time between any pair of ports is assumed to be random and to follow a log-logistic distribution. To deal with random sailing times we propose a two-stage stochastic programming problem with recourse. The routing, the order in which the ports are visited, as well as the quantities to load and unload are fixed before the uncertainty is revealed, while the time of the visit to ports and the inventory levels can be adjusted to the scenario. To solve the problem, a MIP-based local search heuristic is developed. This new approach is compared with a decomposition algorithm in a computational study.

A Maritime Inventory Routing Problem with Constant Rates

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Keywords: maritime inventory routing, mixed integer programming, heuristics

Abstract

We consider a single product maritime inventory routing problem which involves a heterogeneous fleet and multiple production and consumption ports with limited storage capacity. The problem assumes: (i) constant production and consumption rates, (ii) the holding costs are negligible, and (iii) the duration of the route of each vehicle may take several time periods. Assumption (i) is very common in practical problems and, when the demand and production may vary, is it very common to find instances where such approximation is reasonable. Assumption (ii) occurs when the company controls both the inventory level at the producers and consumers, and the holding costs do not depend on the location. Assumption (iii) results naturally on long distance transportation problems such as in maritime transportation. A recent survey on models and instances is given in [6].

A mathematical formulation that follows the continuous time models described in [1,4,5,7] is proposed. The formulation is based on events, which correspond to port visits. The advantage of such formulations in relation to the formulations where the time is discretized, is that the continuous models are smaller and one an solve instances with wider time horizons. On the other hand, such formulations have, in general, large integrality gaps. For a comparison of these models see [3]. In order to solve instances with large time horizons using exact methods, it is important to estimate the number of visits to each port. We propose a heuristic that iteratively increases the number of visits to ports. Then we present a rolling horizon heuristic that splits the time horizon into smaller time horizons and uses the first heuristic in each smaller time horizon. The upper bound values obtained using these heuristics are used to solve a set of instances to optimality by providing good cut-off values for the branch-and-cut algorithm.

A computational study based on a set of instances introduced in [2] is reported.

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A Vessel Pickup and Delivery Problem from the Disruption Management in Offshore Supply Vessel Operations

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Keywords: maritime transportation, disruption management, vehicle routing

Abstract

This paper considers a vessel pickup and delivery problem that arises in the case of disruptions in the supply vessel logistics in the offshore oil and gas industry. The problem can be modelled as a multi-vehicle pickup and delivery problem where delivery orders are transported by supply vessels from an onshore supply base (depot) to a set of offshore oil and gas installations, while pickup orders are to be transported from the installations back to the supply base (i.e. backload). We present both an arc-flow and a path-flow formulation for the problem. For the path-flow formulation we also propose an efficient dynamic programming algorithm for generating the paths, which represent feasible vessel voyages. It is shown through a computational study on various realistic test instances provided by a major oil and gas company that the path-flow model is superior with respect to computational performance.

WA2: Routing: Green Vehicles

Chair: Herbert Kopfer,

Wednesday 10:30-12:30, Room: 6.2.50

Vehicle Routing for Fleets with Electric- and Combustion-Powered Vehicles

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Keywords: vehicle routing, electric-powered vehicles versus combustion-powered vehicles, mixed vehicle fleet, energy consumption, reduction of CO2 emissions, adaptive large neighborhood search

Abstract

Optimal transportation plans for fleets with electric-powered vehicles (EPVs) differ substantially from plans generated for fleets with combustion-powered vehicles (CPVs). The main reasons for this difference are the reduced range and payload of EPVs (compared to CPVs) as well as their increased efficiency. In this paper, transportation plans for CPVs and EPVs which must not be recharged during route fulfillment are analyzed by computational experiments. The advantages of CPVs with respect to totally driven distances, number of used vehicles and the ability to generate feasible plans are opposed to the advantages of EPVs with respect to CO2 emissions. Additionally, it is shown that the specific drawbacks of CPVs and EPVs can be mitigated by exploiting the flexibility of a fleet which is composed of both, EPVs and CPVs.

Routing Problems for Electric Vehicles with Load-Dependent Energy Consumption

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Keywords: electric vehicle routing problem, flow models, discretized models, branch-and-cut

Abstract

One of the most recent generalizations of the classical vehicle routing problem (VRP) is the electric VRP (EVRP). Instead of vehicles with conventional combustion engines, we consider electric vehicles whose range is usually very limited. This natural limitation of electric vehicles forces a regular route optimization to consider an additional level of constraints related to the energy consumption. The reader is referred to [1], [2], [3] and [4], for underlying motivations for this problem and other similar variants. The EVRP is defined on a graph with a depot and a set of clients, with each client having a strictly positive demand. Associated to the graph we have a network of arcs that are defined by their travel cost, the energy consumed by an empty electric vehicle, and the additional energy consumed per load unit. The last two values allow us to determine the total energy consumed by an electric vehicle that utilizes a given arc depending on its current load. Note that these energy consumption values can be negative, which corresponds to downward slopes in which an electric vehicle may recoup some energy. Moreover, we consider a homogeneous fleet with fixed maximum load capacity and state of charge limits. The objective of the EVRP is to find a set of routes with minimal total cost such that each route starts and ends at the depot, each client is visited exactly once, the total demand of all clients on each route does not exceed the maximum load capacity, and the state of charge stays within its limits. Previous literature regarding the EVRP is mainly composed of heuristic-based methods in addition to considering the energy consumption on an arc to not be load-dependent (see, e.g., [3] and [4]). One exception is [5] in which the presented models consider load-dependent energy consumption by using big-M constraints. We propose mixed integer linear programming formulations such that the load-dependent energy consumption is guaranteed by the interaction between two flow systems: one for the energy and another for the vehicle load. The first type of models we propose are flow-based models which are generalizations of single-commodity and multi-commodity flow models for the capacitated VRP (see, e.g., [6], [7] and [8]) to which we add additional energy flow variables that model the energy level of the electric vehicles along the routes. Again, since the energy consumption is

load-dependent, this additional energy flow system will depend on the vehicle load flow system. We follow [9] and also present a specialized load-discretized model, that allows us to disaggregate by load the constraints related to the new energy flow system, leading to improved linear programming relaxation bounds, which can be further enhanced by deriving additional valid inequalities in a layered graph. All models are solved and tested by using branch-and-cut methods.

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The Static Bicycle Repositioning Problem - Literature Survey and New Formulation

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Keywords: bike sharing, bicycle repositioning, routing

Abstract

This paper considers the static bicycle repositioning problem (SBRP), which deals with optimally re-balancing bike sharing systems (BSS) overnight, i.e. using service vehicles to move bikes from (nearly) full stations to (nearly) empty stations. An exhaustive literature survey comparing existing models is presented, and a new and improved mathematical formulation for the SBRP is proposed. The model is tested on a number of instances generated on the basis of data from a real BSS.

Service Network Design of Bike Sharing Systems with Resource Constraints

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Keywords: bike sharing systems, bike redistribution, tactical planning, service network design, master tours

Abstract

Station-based bike sharing systems provide an inexpensive and flexible supplement to public transportation systems. However, due to spatial and temporal demand variation, stations tend to run full or empty over the course of a day. In order to establish a high service level, that is, a high percentage of users being able to perform their desired trips, it is therefore necessary to redistribute bikes among stations to ensure suitable time-of-day fill levels. As available resources are scarce, the tactical planning level aims to determine efficient master tours periodically executed by redistribution vehicles. We present a service network design formulation for the bike sharing redistribution problem taking into account trip-based user demand and explicitly considering service times for bike pick-up and delivery. We solve the problem using a two-stage MILP-based heuristic and present computational results for small real-world instances. In addition, we evaluate the performance of the master tours for multiple demand scenarios.

WB1: Container Terminals & Stowage I

Chair: Shell Ying Huang,

Wednesday 14:00-16:00, Room: 6.2.53

A New Lower Bound for the Unrestricted Blocks Relocation Problem

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Keywords: blocks relocation problem, container relocation problem, branch-and-bound algorithm, lower bound

Abstract

Consider a bay composed of S stacks where a total of N blocks (containers) are piled up in tiers, and the number of blocks in a stack is restricted to T. A block in the j^{th} tier of stack i is referred to as block (i, j), and block (i, j) is given a unique integer priority value Pij ($1 \leq Pij \leq N$) where a smaller value means a higher priority. We want to retrieve all the blocks from the bay according to their priorities by the following two crane operations: Retrieval is to remove the block with the highest priority from the bay if it is on the top of a stack. Relocation is to move a topmost block of a stack to another stack. The objective of the block(s)relocation problem or container relocation problem is to find an optimal sequence of these operations that minimizes the number of relocations. Two variants of the block relocation problem (BRP) have been studied in the literature. In the restricted BRP, only the topmost block of the stack that includes the block with the highest priority (the block to be retrieved next) is relocatable, on the other hand, all the topmost blocks are relocatable in the unrestricted BRP. For the restricted BRP, an efficient branch-and-bound algorithm [1] was proposed based on [2]. Then, it was extended to the unrestricted BRP [3, 4]. In this study, we will improve the lower bound for the unrestricted BRP proposed in [5]. This enables us to improve the efficiency of the algorithm in [4] that employs the lower bound in [5]. Its effectiveness will be demonstrated by numerical experiments.

The lower bound for the unrestricted BRP in [5] is improved as LB3 for the restricted BRP in [2]. A block who has a block with a highest priority beneath it is referred to as a blocking block here. Obviously, a blocking block should be relocated at least once, so that the number of blocking blocks gives a lower bound of the number of relocations [6]. In [5] this lower bound is increased by one when all the topmost blocks become blocking blocks even after relocation. In the proposed lower bound, whether the lower bound can be increased by one is checked for the blocks above the target block (the block with the highest priority in the current configuration).

If no, the same check is applied for the configuration after the blocks as well as the target block are removed. It is repeated until all the blocks are removed.

H	*S*	*N*	*n*	[4] with [5]		[4] with proposed		[8][a]	[9][b]
				ave (s)	max (s)	ave (s)	max (s)	solved	solved
3	3	9	40	0.00	0.00	0.00	0.00	**40**	**40**
3	4	12	40	0.00	0.00	0.00	0.00	**40**	**40**
3	5	15	40	0.00	0.00	0.00	0.00	**40**	**40**
3	6	18	40	0.00	0.00	0.00	0.00	**40**	**40**
3	7	21	40	0.00	0.00	0.00	0.00	**40**	**40**
3	8	24	40	0.00	0.00	0.00	0.00	**40**	**40**
4	4	16	40	0.00	0.00	0.00	0.00	**40**	**40**
4	5	20	40	0.00	0.02	0.00	0.01	**40**	**40**
4	6	24	40	0.01	0.12	0.00	0.03	**40**	**40**
4	7	28	40	0.02	0.38	0.00	0.03	5	39
5	4	20	40	0.04	0.58	0.02	0.30	**40**	**40**
5	5	25	40	1.19	39.87	0.42	11.68	25	37
5	6	30	40	3.87	96.62	0.82	19.96	1	30
5	7	35	40	27.94	827.94	4.76	151.87	1	25
5	8	40	40	184.62	3597.18	17.71	495.23	0	17
5	9	45	40	107.15	3231.74	10.17	242.98	0	13
5	10	50	40	369.94	7938.52	16.38	256.20	0	9

Table 1: computational results for benchmark instances ($T = H + 2$); *[a] Java SE 7, run on an Intel Core 2 Duo E8500 CPU (3.16GHz) with a time limit of 24h. [b] Python, run on an Intel Xeon E5-2670 v2 CPU (2.50GHz) with a time limit of 1h.*

The lower bound in [5] was employed in the algorithm [4]. It is replaced with the proposed lower bound and the average and maximum CPU times are compared in Table 1 for the benchmark instances in [7]. The computation was performed on a computer with an Intel Core i7-2700K CPU (3.5GHz). The numbers of instances solved to optimality within a time limit are also shown for the algorithms in the literature [8, 9]. Clearly, the previous algorithm [4] with [5] already outperforms those in [8, 9], and its efficiency further improves by the proposed lower bound.

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A Matheuristic for Block Stowage Planning with Crane Intensity

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Keywords: stowage planning, matheuristics, liner shipping

Abstract

With nowadays ultra large container vessels with a capacity of over 19,000 Twenty Equivalent Units (TEUs), the industry is realizing the need to used advanced planning methods to help the decision making of stowage planners. In recent years, there has been an increase focus on stowage planning also in the academic literature. Starting from the seminal work of [2], where the basic combinatorial nature of overstowage was studied. Overstowage refers to the situation where a container to be discharged is stowed below a container destined to a future port; such a situation would then require extra moves at port, and is thus undesirable.

Works on stowage planning then started to add more industrial constraints, which resulted in research on decomposition models e.g. [7], [4] and [1]. More recently, industrial strength models that could also handle hydrostatic stability constraints were presented in [5, 6].

The cost of overstowage is however to high, and stowage planners are not willing to risk having plans where such situations are possible. The concept of block stowage is thus being used more and more. Block stowage is the partition- ing of the vessel into blocks which will then only be allowed to have containers of the same discharge port. The blocks often correspond to the areas above and below a hatch cover (a water tight structure that between the above and below deck area). Aside from this, the concept of crane intensity has also been included in the planning decision. Crane intensity is the total number of con- tainer moves divided by the crane with the highest activity. This measure is used as a KPI by the industry to arrange cargo on the vessel so that it best targets the number of cranes available at port.

The use of block stowage with the aim of reaching a specifc crane intensity, turns out to be too complex for the current state-of-the-art mathematical approaches. There is thus now a need to nd e cient solution methods to solve the combinatorial complexity of the new constraints and objectives. We present a novel mathematical formulation for the basic Block Stowage with Crane Intensity, and show preliminary results on a mathheuristic based on the same formulation.

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A Cooperative Approach to Dispatching and Scheduling Twin-Yard Cranes in Container Terminals

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Keywords: yard crane dispatching and scheduling, optimization, container terminal

Abstract

To increase the productivity of the storage yard of a container terminal, two identical yard cranes are often deployed in a yard block. In theory, the productivity of a yard block may be doubled with twin-cranes. However, crane interference may severely lower the combined productivity of the twin-cranes. In this paper, we propose an online job dispatching method for twin yard cranes when side loading is used. The method adopts the non-zero-sum game approach to induce the cooperative behaviour in the dispatching and scheduling of jobs for the two cranes to minimize the total job completion time. A one-step lookahead algorithm and a two-step lookahead algorithm are proposed. We evaluate our algorithms against Ng's lower bound of total completion time for twin-cranes and against the greedy heuristic Smallest Completion Time-First. Our experiments showed that our dispatching and scheduling algorithm performs very well.

Agent-Based Support for Container Terminals to make Appointments with Barges

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Keywords: terminal planning, quay scheduling, dynamic assignment, multi-agent system simulation

Abstract

We consider a container terminal that has to make appointments with barges dynamically with only limited knowledge about future arriving barges, and in the view of uncertainty and disturbances. We study this problem using a case study at the Port of Rotterdam, considering a proposed multi-agent system for aligning barge rotations and terminal quay schedules. We take the perspective of a single terminal participating in this system and focus on the decision-making capabilities of its intelligent agent. Using simulation, with input settings based on characteristics of the larger terminals within the Port of Rotterdam, we analyze the benefits of our approach. We conclude that a terminal can increase its utilization significantly by using various sources of flexibility in the operational planning.

WB2: Routing I

Chair: Ana Pereira,

Wednesday 14:00-16:00, Room: 6.2.50

A Branch-and-Price Algorithm for the Vehicle Routing Problem with 2-Dimensional Loading Constraints

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Keywords: vehicle routing, loading constraints, branch-and-price, computational study

Abstract

In this paper, we describe a branch-and-price algorithm for the capacitated vehicle routing problem with 2-dimensional loading constraints and a virtually unlimited number of vehicles. The column generation subproblem is solved heuristically through variable neighborhood search. Branch-and-price is used when it is not possible to add more attractive columns to the current restricted master problem, and the solution remains fractional. In order to accelerate the convergence of the algorithm, a family of valid dual inequalities is presented. Computational results are provided to evaluate the performance of the algorithm and to compare the different branching strategies proposed.

Generalized Vehicle Routing Formulation for Mass Rescue Operations in Ocean Waters

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Keywords: combinatorial optimization, vehicle routing, maritime applications

Abstract

Mass rescue operations (MRO) in maritime areas, particularly in ocean areas, are a major concern for the authorities responsible for conducting search and rescue (SAR) activities (IAMSAR 2014). A mass rescue operation can be defined as a search and rescue activity characterized by the need for immediate assistance to a large number of persons in distress, such that the capabilities normally available to search and rescue are inadequate. In this paper we deal with a mass rescue operation within ocean areas and we consider the problem of rescuing a set of survivors following a maritime incident (cruise ship, oil platform, ditched airplane) that are drifting in time. The recovery of survivors is performed by nearby ships and helicopters. We also consider the possibility of ships capable of refueling helicopters while hovering which can extend the range to which survivors can be rescued.

We propose an approach to solve the rescue problem based on a (huge) layered graph, discretized by time where arcs between time-indexed nodes are feasible only if the ships or helicopters are allowed to travel within the given time ranges. In the recent past, integer linear programming formulations based on similar layered graphs have proved to lead to very strong formulations for several network design problems (Gouveia, L., et al, 2011; Gouveia et al, 2015).

We propose a linear binary formulation which is similar to the well-known Picard and Queyranne formulation for the time-dependent traveling salesman (Picard, J. C., & Queyranne, 1978 and Gouveia, L. e Voβ, S., 1995).

The problem considered in this work can be viewed as an extension of the generalized vehicle routing problem (GRVP) with a profit criteria since we may not be able to recover all of the survivors.

Due to the huge graphs obtained in this way we also propose and evaluate heuristic methods based on adaptations of the nearest neighbor heuristic as well as look-ahead methods (Fernandes et al, 2007 and Duin and Voβ, 1999).

We also developed an application in order to create several instances of the mass rescue problem with different sizes and operational characteristics (distance between survivors to shore, decay of survivor's health in water, available helicopters, nearby ships location, weather conditions). The results produced by the constructive heuristics where compared depending on taking (or not) into account information regarding survivability times. The results show that the availability of this information is relevant to the efficacy of the rescue solution. Recently, there has been several studies (Vazquez, 2010 and Medved et al, 2004) to developed technology that allows cellphones to be used as useful search beacons. Computational results show that the heuristics that take into account information regarding survivability time perform better in scenarios where a large number of SAR units are available when compared to nearest neighbor constructive heuristics. Also, a few results taken from some of these instances show that look-ahead based heuristics provide better results when compared to simple constructive heuristics.

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A Hybrid Metaheuristic for Planning Vessel Routes in Fishery Surveys

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Keywords: heuristics, genetic algorithms, benders decomposition, routing problems, traveling salesman problem

Abstract

To study the abundance of fish species, a research vessel must visit a set of predefined locations, fishing stations, each location being visited exactly once, within predefined time windows. The survey tour is divided into two circuits, each circuit starting and ending at a home port and lasting at most |H| days. According to a predefined periodicity, each circuit must visit one of the available selective ports to get food supplies, refuel, and/or change crew.

Environmental concerns call for the minimization of traveled distance. Actually, minimizing the traveled distance results in less fuel and oil consumption, which in turn reduces environmental emissions as well as sea pollution. From the management and staff point of view, it is desirable to minimize the completion time in order to return home as soon as possible. Hence, the staff intends to sample as many fishing stations as practicable, in each day. Since the number of visits to fishing stations is limited by predefined time windows, the completion time depends on the vessel's traveled distance and the waiting time before starting fishing operations, at the beginning of the day. So, instead of being idle at a closer location waiting to start the fishing operation, it might be advantageous to cover long distances at night to first visit fishing stations far away. Consequently, the shortest path in distance will not necessarily be the shortest path in time. The vessel route optimization problem (VROP) consists of finding a feasible route for the research vessel that minimizes a linear function of the traveled time and completion time. This problem is NP-hard, as it is a generalization of the traveling salesman problem, justifying the search for efficient heuristics approaches to solve it.

Traditionally, when dealing with difficult combinatorial optimization problems that arise in real life, optimizers either use mathematical programming-based approaches or metaheuristics. However, the use of hybrid metaheuristics, combining both techniques has been increasing in the last decade (see e.g. [1], [2], [3]).

We present a mixed-integer linear programming (MILP) model for the VROP. Two subproblems may be identified in the MILP model: i) a routing subproblem that defines the order by which fishing stations, and eventually a selective port, are visited while minimizing the traveled time distance; ii) a scheduling subproblem that determines the starting time of each visit while minimizing the completion time.

Taking advantage of the structure of the mathematical model, we propose a hybrid metaheuristic that iterates between two steps. In the first step a genetic algorithm is used to obtain feasible solutions for the VROP. Each solution is represented as a permutation of the set vertices corresponding to the fishing stations and to four replicas of the home port. These replicas simulate the starting and ending location of each circuit. Each permutation defines two circuits starting and ending at the home port, but without including the selective ports. Then, a decoder is used to establish the starting time of each visit, assuring the validity of time windows, as well as the visit to a selective port, if necessary, within the corresponding time window. Although the decoder algorithm gives the objective function value for the current solution, the fitness function to be maximized, is defined as the reciprocal of the corresponding total tour length, being the optimization of the completion time addressed in the next step.

In step 2, a perturbation procedure is applied to the current solution. A heuristic procedure, that uses primal dual relationships, is developed to obtain a feasible dual solution for the linear programming relaxation of the scheduling subproblem. Following Benders decomposition philosophy, a Benders cut is built, based on the dual solution, and is relaxed to the objective function perturbing solutions given by the genetic algorithm. The process alternates between step 1 and step 2 for a fixed number of iterations aiming to improve the diversity in the genetic algorithm and helping to escape from local optima.

The computational experience undertaken with reality-based instances shows that, at low computational expenses, the feedback given by the perturbation procedure guided the building of the two circuits. The resulting solutions are compared to solutions previously obtained [4] by applying sequential approaches that combine genetic algorithms with local search.

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WC1: Intermodal Transportation

Chair: An Caris,

Wednesday 16:30-18:30, Room: 6.2.53

A Revenue Management Approach for Network Capacity Allocation of an Intermodal Barge Transportation System

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Keywords: revenue management, network capacity allocation, intermodal barge transportation, probabilistic mixed integer model

Abstract

We propose a revenue management (RM) model for the network capacity allocation problem of an intermodal barge transportation system. Accept/reject decisions are made based on a probabilistic mixed-integer optimization model maximizing the expected revenue of the carrier over a given time horizon. Probability distribution functions are used to characterize future potential demands. The simulated booking system solves, using a commercial software, the capacity allocation problem for each new transportation request. A conventional model for dynamic capacity allocation considering only the available network capacity and the delivery time constraints is used as alternative when analyzing the results of the proposed model.

Analysis of Cost Allocation Techniques for Freight Bundling Networks in Intermodal Transport

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Keywords: cost allocation, consolidation, intermodal transportation, shipper collaboration

Abstract

In order to improve the competitive position and efficiency level of intermodal transport, consolidation of freight flows is often suggested. Bundling networks require cooperation between multiple partners in the intermodal transport chain. In this context, the question rises how benefits may be allocated fairly among the participants in the cooperation. A great deal of scientific literature reports on the behavior of allocation methods in collaborations between shippers or carriers making use of unimodal road transport. However, research on cost or gain allocation methods in intermodal transport is scarce. The main contribution of this paper is thus to provide a first insight in the complexity of sharing gains fairly amongst shippers who bundle freight flows in order to reach economies of scale in intermodal transport. By applying three different allocation methods, a comparison is made between simple and straightforward allocation mechanisms and more advanced techniques based on cooperative game theory. The situation of three-, four- and five-partner coalitions is investigated, both for partners with an equal and an unequal amount of shipments. For these six situations, the case of a common barge trajectory and a common end terminal are studied.

Optimizing Train Load Planning: Review and Decision Support for Train Planners

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Keywords: train load planning, intermodal transportation, container terminals, rail transportation

Abstract

Train load planners are confronted with complex practical considerations during the booking and planning process. In order to optimally utilize the available loading space, train capacity is monitored in terms of available length and weight while accounting for the urgency with which load units must be sent. Furthermore, the execution of the load plan by the terminal operator must be performed efficiently to minimize total handling costs. The contribution of this paper is threefold. First, current literature on train load planning is reviewed based on three main groups of factors influencing the load plan composition. Second, a static model is developed to introduce a number of practical constraints from the viewpoint of the network operator. Finally, the model is adapted to reflect the planning environment of a real-life case study.

A Simulation-Optimization Approach for Intermodal Transport Planning under Travel Time Uncertainty considering Multiple Objectives

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Keywords: simulation-optimization, sustainability, service network design, transport planning, robust optimization

Abstract

The growing globalization of today´s world contributes to the increasing number of supply chain actors and increasing distances between them. In order to stay competitive in this situation, an effective design and execution of supply chain operations is highly important for each company. This is especially true for transport operations which are necessary for moving goods between the individual actors and can lead to high costs and problems at different stages of a supply chain caused by various disruptions.

The aim of transport planning at the operational level is to find the optimal route which enables the delivery of goods from origin to destination within a defined time frame while minimizing the transport costs. As this can be relatively easily achieved by using road transport with its direct door-to-door delivery and dense transport network, truck transport is usually the preferred transport option as it can be seen on its high share on the modal split in Europe. However, the growing volumes of road transport and the limited network infrastructure lead to disruptions (e.g. congestion, accidents etc.) which might result in the delayed delivery of goods. Therefore the reliability of transport is also becoming an important decision criterion in transport planning. Moreover, road transport is responsible for a significant part of the CO2 emissions from transport which have negative impact on the environment. As a result, companies are searching for alternative transport modes that can fulfil their requirements.

One of the alternatives is the combination of at least two transport modes within an intermodal transport chain where the goods are transported in the same transport unit (e.g. container). In

this way the flexibility of a truck needed for the pick-up and final delivery of goods can be combined with the economic and environmental advantages of long-distance rail or waterway transport using standardized equipment for transhipment of goods between transport modes. Although this transport alternative might be advantageous in comparison to direct road transport, intermodal transport networks are usually more complex and require coordination between the different transport services, which are in most cases running according to fixed schedules. Therefore advanced planning algorithms are needed that can find the optimal transport plan and ensure its reliability without extensive buffer times in the terminals.

In order to take all these requirements into account, we used a service network design (SND) approach to develop a planning algorithm for intermodal transport operations. This approach enables to represent every transport connection as a service with its specific characteristics, including origin, destination, departure time, travel time, capacity, transport costs, CO2 emissions and vehicles which will be transporting the goods. Moreover, the proposed mixed-integer linear program combines the traditional economic objective of transport cost minimization with additional objectives including time (in form of penalty costs for delayed delivery) and emissions (as penalty cost per ton of CO2 emissions). In this way, the decision-maker can choose whether he wants to achieve minimal costs, minimize the environmental impact of transport or combine all three objectives by assigning different weights to each of them. Reliability aspect is included by considering stochastic travel times with different possible realizations (uncongested, congested, disrupted) which are tested in different scenarios and a chance constraint ensures that only plans which are feasible in most (e.g. 95%) of the cases are chosen.

Although the proposed model can find the optimal solution within seconds, the high number of constraints in the stochastic version of the model limits the size of instances which can be solved. Therefore we propose a simulation-optimization approach which combines the SND model with simulation. In this approach, the SND model is used in the first step to find the optimal route for multiple orders using deterministic travel times. After that the optimal routes are tested in a simulation which uses stochastic travel times to evaluate the robustness of the chosen plan. The simulation combines an agent-based and a discrete-event approach in which orders and transport services are modelled as agents that can interact with each other within the transport and transhipment processes. During the simulation, a number of scenarios are tested in which the travel times for each service are chosen randomly from the three possible realizations (uncongested, congested, disrupted). After each run, the feasibility of the plan as well as the total cost, arrival time and total emissions are recorded. In case of infeasibility of a plan, goods are transported directly to their final destination from the terminal where the plan became infeasible at higher cost. In this way not only probability that a plan becomes infeasible can be measured but also the additional costs and emissions as well as the arrival time in case of infeasibility can be measured. Besides that, the simulation allows to run a higher number of scenarios in comparison to the original stochastic SND model. If the transport plan for a specific order is evaluated as unreliable, an alternative plan has to be found using again the optimization model. The new plan is then evaluated by the simulation and this process is repeated until a robust plan is found for each order.

The described approach is tested on a real-world case study using the available schedules of intermodal services including road, rail and inland waterway. The transport costs and emissions per container for each service are estimated using different models for each transport mode considering specific characteristics of each service. The results show the influence of different objectives on the optimal route and the robustness of each plan. Although the presented model can be currently used mainly for creating robust transport plans before the start of the transport (offline planning), it can be adapted to react also on disruptions happening during transport execution that are not covered by robust offline plans and where a quick reaction is needed (online planning).

WC2: Scheduling and Routing

Chair: Marta Mesquita,

Wednesday 16:30-18:30, Room: 6.2.50

Adaptive Large Neighborhood Search for the Technician Routing and Scheduling Problem

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Keywords: technician routing and scheduling problem, insertion heuristic, ALNS, vehicle routing problem

Abstract

In this paper, we address a new variant of the Technician Routing and Scheduling Problem (TRSP). This problem is motivated by a real-life industrial application in Telecommunication Company. It is defined by a set of technicians having distinct skills that could perform a set of geographically scattered tasks over a multi-period horizon. Each task is subject to time constraints and must be done at most once over the horizon by one compatible technician. The objective is to minimize the total working time (composed by routing time, service time and waiting time), the total cost engendered by the ejected tasks, and the total delay. To solve the problem, we propose ten variants of vehicle routing insertion heuristic and an Adaptive Large Neighbourhood Search (ALNS) with specific constructive and destroy operators. Computational experiments are conducted on 20 instances with up 550 tasks to evaluate and to compare the performances of the proposed approaches. The results confirm the effectiveness of the ALNS approach.

Truck Driver Shift Scheduling in Vehicle Routing with Time-Dependent Service Costs

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Keywords: vehicle routing, dynamic programming, general time-windows, multiple trips, truck driver scheduling, hours of service

Abstract

Our research is motivated by a real-life vehicle routing problem (VRP) which commonly occurs when goods are delivered to grocery stores. This problem shares the characteristics of three enhancements of the classical VRP. The first enhancement is to expect a time-dependent service cost function for every delivery order as input, instead of hard or (still less general) soft time windows. Such a function reflects how inopportune the delivery is at a certain point in time. For instance, it may be more inopportune the busier the employees of the grocery store are with other tasks, so they might not place the goods in the store soon enough after their delivery. Vehicle routing with time-dependent service costs was introduced by [Ibaraki et al., 2005] as the vehicle routing problem with general time windows. Grocery stores usually have a separate room for night-time delivery when the stores are closed. But while goods can be delivered anytime, drivers cannot work an arbitrarily long time. Hence drivers alternate in shifts, i.e., every vehicle can be used multiple times per day. For a planning horizon of one day, usually three shifts and thus three trips are planned. This is the second enhancement. For a survey on the vehicle routing problem with multiple trips, see [Cattaruzza et al., 2016].

As the third enhancement, we are given a maximum shift duration as input. So each trip must not exceed this duration. Also, drivers have to respect break and rest rules. The regulation 561/2006 of the European Union states that after driving for at most 4.5 hours, drivers have to take a break of at least 45 minutes. W.l.o.g. we may expect that the maximum shift duration is short enough so that we do not have to consider longer breaks, e.g. a daily rest period of several hours. This constitutes (a variant of) the vehicle routing and truck driver scheduling problem as described by [Goel and Vidal, 2014].

Problem Definition The combination of these three enhancements has not been studied before. Because of the complexity of the problem, we examine the routing and the scheduling part separately, with a focus on the scheduling part. For this, we now give a slightly more formal definition:

For a vehicle, let a sequence of trips be given, and let a trip be a sequence of customers. For each customer, there is a service time and a function that maps the delivery time to some non-negative costs. Furthermore, the driving time between two consecutive customers is known.

For each trip, we are looking for a driver schedule. A feasible driver schedule respects the driving times, the service times, the break rule, and the maximum shift duration. A driver schedule determines the delivery time at each customer, and so one can compute the costs of a trip as the sum of costs at each customer. A vehicle schedule is a sequence of driver schedules. It is feasible if all its driver schedules are feasible and no driver schedule starts earlier than the previous driver schedule ends. The objective is to find a feasible vehicle schedule with minimum overall costs.

We call this the minimum service cost truck driver shift scheduling problem. This subproblem of our real-life vehicle routing problem has not been studied before either.

Solution Approach [Ibaraki et al., 2005] present a dynamic programming algorithm to find a schedule with minimum cost for a single trip without regard of breaks or a maximum duration. More precisely, they iterate over the customers and maintain a forward minimum cost function that maps a time t at the current customer i to the minimum service costs such that customer i and all predecessors are served at time t or earlier. For this, they demand the service cost functions to be piecewise linear. To account for a maximum duration, we need to enhance this approach and maintain a sequence of such functions, one for each significant trip start time. A break may be reasonable between every two consecutive customers, so we need to handle i many function sequences in iteration i if we want to respect the break rule. This way, we can find the least cost of a feasible driver schedule for every trip start time and every trip end time. To find an optimum solution for a sequence of trips, we need to apply an appropriately defined function composition.

[Ibaraki et al., 2005] demonstrate how to efficiently incorporate their DP algorithm into local search algorithms for the routing part of the problem. The key aspect is to also compute a backward minimum cost function. We will also show how to apply this speed-up technique in our context.

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Automated Workforce Scheduling in Airport Logistics

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Keywords: rostering, staff scheduling, airport logistics, ground handling, large-scale optimization

Abstract

We present a major research and business project aimed at developing efficient and flexible software for automated staff scheduling in airport logistics. Industrial partner is Swissport International, the largest ground handling company worldwide, and pilot site for the project is Zurich Airport in Switzerland. Swissport provides services for 230 million passengers and 4 million tons of cargo a year, with a workforce of 61'000 personnel at 290 airports. Airport ground handling involves a broad range of different tasks, including passenger services like check-in, gate handling and transfer services, and ramp services like baggage management and aircraft handling, servicing and cleaning.

The diversity of the ground handling functions at Zurich Airport, the large number of operational duties, and the around-the-clock business hours result in hundreds of different types of shifts to be planned every month, and an employee base consisting of several thousand persons with numerous different skills. Further challenges come from a dynamic, demand-driven planning policy which does not rely on repetitive shift patterns rolled out over a long-term horizon, and from a so-called shift-bidding approach which attributes high importance to employee preferences regarding the individual work plans.

We start with an introduction to the business environment of the project, and show its actual planning context which comprises other software tools and human planning activities related to the workforce scheduling process. We discuss the various project requirements and the challenges and goals that shaped the project and the used methods.

Employee scheduling typically involves a number of subproblems including demand modeling, shift design, days-off scheduling, and shift assignment. The rostering process considered here focuses on the days-off planning and shift assignment phase.

The methodology used for solving the associated complex large-scale optimization problems comprises a broad range of optimization techniques including preprocessing, decomposition

and relaxation approaches, large-scale integer programming models, and various heuristic procedures.

We provide insight into several aspects of the solution process, with special focus on the analysis and preprocessing phase which turned out to be crucial for the entire planning system. An important purpose of this phase is to deal with feasibility issues related to incorrect or inconsistent input data. In fact, experience shows that most of the operational instances submitted to the planning tool are infeasible, and detecting and patching the infeasibility is typically difficult. Without specific hints from the software it is virtually impossible for the human planners to discover the causes of infeasibility, and to adjust the input data accordingly. The tools developed for this planning phase range from simple but thorough data checking and analysis modules to sophisticated mathematical models for bottleneck analysis, identification of minimal infeasible constraint systems, and rapid presolving techniques.

Finally, we present computational experience with real world instances and discuss operational impacts of the developed planning tool. The operational deployment started at Zurich Airport and is continually being extended to other international airports. Bottom-line benefits include faster and more robust planning processes, improved roster quality, better fairness, reduced planning capacity requirements, and as a result, substantial financial savings.

Continuous-Time Formulation for Oil Products Transportation Scheduling

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Keywords: transportation, MILP, pipeline networks, continuous representation

Abstract

This paper presents a novel Mixed Integer Linear Programming (MILP) model for the operational planning of an oil transportation system characterized by a straight multi-product pipeline with dual purpose terminals. It is based on a continuous representation in both time and volume scales and is capable of meeting all operational constraints related to product sequencing, mass balances and depot loading/ unloading operations. Contrary to previous approaches, the model allows an intermediate node and the previous segment to simultaneously inject material in the pipeline. Two case studies are used to illustrate the advantages of the proposed model.

TA1: Maritime Transportation II

Chair: Kevin Tierney,

Thursday 10:15-12:15, Room: 6.2.53

Scenarios for Collaborative Planning of Inter-Terminal Transportation

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Keywords: inter-terminal transportation, collaborative transportation planning, first-price auction, forwarding profit, collaboration profit

Abstract

The immense growth of containerized transport and the increasing frequency of calls of mega-vessels at terminals serving as transshipment points, require powerful planning methods for the efficient fulfillment of inter-terminal transportation tasks. Collaborative planning, and in particular the exchange of tasks among carriers, is a promising instrument for increasing the efficiency of inter-terminal transportation. The exchange of tasks can be organized by auctions performed by the carriers. Three different collaborative planning scenarios are presented in this paper. These scenarios are evaluated by computational experiments. Based on the preferences of terminal operators and the outcome of computational experiments, recommendations for collaborative inter-terminal transportation are derived.

A Logic-Based Benders Decomposition Approach to Improve Coordination of Inland Vessels for Inter-Terminal Transport

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Keywords: constraint programming, benders decomposition, vessel rotation planning

Abstract

Large seaports usually contain multiple terminals serving container vessels, railways, trucks and other modes of hinterland transportation. Every time an inland vessel enters a seaport, it visits several terminals for loading and unloading containers. A vessel rotation is the sequence in which a vessel visits the different terminals in a large seaport. Currently, in a seaport like the port of Rotterdam, around 40% of the inland vessels have to spend a longer time in the port area due to the low utilization of terminal quay resources and uncertainty of waiting times at different terminals. To better utilize the terminal resources in the ports, as well as to reduce the amount of time inland vessels spend in the port area, this paper first proposes a new model in which inland vessels coordinate with each other with respect to the arrival, departure time and the number of inter-terminal containers carried, besides their conventional hinterland containers, with the aim to prevent possible conflicts of their rotations. Then a logic-based Benders' decomposition approach is proposed to minimize the total time the inland vessels spent in the port. We compare the performance of the proposed approach with the performance of a centralized approach on the aspects of the runtime, solution quality, and three logistical performance indicators. Simulation results show that the proposed approach generates both faster optimal and faster high-quality solutions than the centralized approach in both small and large problem instances.

Path Planning for Autonomous Inland Vessels using A*BG

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Keywords: autonomous vessels, path planning, A*BG, navigation regulations, inland waterway system

Abstract

To meet the transportation demand and maintain sustainable development, many countries are aiming to promote the competitive position of inland waterway shipping in the transport system. Autonomous transport is seen as a possibility for maritime transport to meet today's and tomorrow's challenges. In realizing autonomous navigation, path planning plays an important role. Being the most widely used path planning algorithm for robotics and land-based vehicles, in the paper, we analyze A* and its extensions for waterborne applications. We hereby exploit the fact that for vessels, optimal paths typically have heading changes only at the corners of obstacles to propose a more efficient modified A* algorithm, A*BG, for autonomous inland vessels. Two locations where ship accidents frequently occurred are considered in simulation experiments, in which the performance of A*, A*PS, Theta* and A*BG are compared.

Modelling Bunker Consumption for Optimization Models in Maritime Transportation

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Keywords: maritime transportation, bunker consumption, computational analysis

Abstract

Seaborne trade plays a major role in the world economy and is responsible for the transportation of about 9.8 billion tons of goods per year [13]. For the transportation of these large volumes, shipping companies around the world have established a large fleet.

One of the main costs of operating a seagoing vessel is the cost of bunker fuel [11]. A vessel can consume dozens of tons of fuel per day, and takes on a major role in the costs of a shipping company. Reducing fuel consumption has thus become a central goal within the industry. In addition to saving money, reducing fuel consumption cuts CO2 emissions. Therefore, modelling variable speed has become a key component of maritime optimization [7].

Bunker consumption varies approximately cubically with the speed of a ship (see, e.g., [3])[1] and proportionally to factors such as load and trim. When including variable vessel speed in an optimization model, researchers must decide how to model bunker consumption. Often it is linearized in a piecewise fashion (as in [5] and [10]), but some have modeled it using second order cone programming or other non-linear techniques (see [4]). Most authors choose a particular approximation (e.g., number of break points or a non-linear approach) and use it throughout their work. However, there is no rigorous study that analyzes the a effect of the various approximations of bunker consumption on the solution quality and the runtime of optimization approaches. We study the tradeoff between more exact models of bunker consumption on optimization model runtime and solution quality to help modelers find the best accuracy for their application.

We now discuss some different models of bunker consumption in the literature. In the work of [1], a model is presented to jointly solve the routing and deployment of container vessels. [1] considers bunker consumption as a cubic function, but discretizes it for the computational analysis. [8] include a non-linear cost function for the bunker consumption in their model for

[1] Some works suggest a higher-order polynomial (e.g., [4]).

tramp ship routing and scheduling. [8] present a heuristic to solve this problem and compare this approach to the solutions of a non-linear programming solver in a computational study. Contrary, publications like [6] and [12] use a linearized bunker consumption function for their optimization models. Whereas [6] propose a model for planning strategies of vessel arrivals, [12] present a model to solve the liner shipping fleet repositioning problem. Furthermore, [2] propose a piecewise linearization for the speed optimization in their fleet deployment model. We refer to [9] for an extensive taxonomy of papers about speed optimization of vessels that gives an overview of the various formulations of the fuel consumption function.

We performed preliminary computational experiments by using the model for cargo allocation of [5]. This model considers service levels and is able to optimize the speed of the vessels. In their analysis, [5] use instances drawn from the LINERLIB [3]. The instances are drawn from two different regions with each having 30 instances of varying sizes.

In order to analyze the influence of the selection of breakpoints for the piecewise approximation, we use six different values as depicted in Table 1 together with our preliminary results. For each breakpoint value, the table shows the runtime and solution quality in relation to the column with the biggest breakpoint value (100). Each cell shows the deviation from the results with 100 breakpoints as a percentage. For small scenarios like the Baltic instances, less breakpoints provide significantly less runtime without much increase in the error in the objective value. However, on the larger WAF instances we see a different picture. As expected, the error in the objective value decreases with a growing number of breakpoints, however time is only saved at 50 breakpoints.

Region	2		3		5		10		20		50		100	
	sol	time	sol	time	sol	time	sol	time	sol	time	sol	time	sol	time
Baltic	-2.15	-80.02	-1.00	-80.02	-0.44	-77.77	-0.14	-74.30	-0.05	-70.54	-0.01	-46.64	0.00	0.00
WAF	-17.08	106.75	-9.27	31.42	-4.46	15.65	-1.82	40.63	-0.73	11.66	-1.19	-4.59	0.00	0.00

Table 1: Experimental results in percentages, taking the column for 100 breakpoints as 100%. These are averages over 30 instances. The columns "sol" show the relation of the optimal solution and the columns "time" show the relation of the CPU time

These results show that analyzing the selection of different configurations for the optimization of bunker consumption lead to interesting results and in order to fully understand the details, more experiments are necessary. Therefore, we intend to do this experiment for the model of [5] with further instances. Additionally, we are going to do similar experiments with different models in order to compare the effects of various approximations. Finally, we will add an analysis of nonlinear models to our evaluation. By aggregating these evaluations, we seek to provide an answer to the question how the bunker consumption can be approximated, such that the effort is reduced. With this reduction, mathematical models become more interesting for shipping companies and can increase their contribution to the saving of costs and emissions of these companies.

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TA2: Simulation in Logistics

Chair: Katrien Ramaekers,

Thursday 10:15-12:15, Room: 6.2.50

Improving Order Picking Efficiency by Analyzing Combinations of Storage, Batching, Zoning, and Routing Policies

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Keywords: order picking, storage, order batching, zone picking, routing, warehouse policies, interactions

Abstract

In order to differentiate from competitors in terms of customer service, warehouses accept late orders while providing delivery in a quick and timely way. This trend leads to a reduced time to pick an order. The objective of this research is to simulate and evaluate the interaction between several storage, batching, zone-picking and routing policies in order to reduce the order picker travel distance. The value of integrating these four operation policy decisions is proven by a real-life case study. A full factorial ANOVA provides insight into the interactions between storage, batching, zoning, and routing policies. The results of the study clearly indicate that warehouses can achieve significant benefits by considering storage, batching, zone picking, and routing policies simultaneously. Awareness of the influence of an individual policy decision on the overall warehouse performance is required to manage warehouse operations, resulting in enhanced customer service.

An Agent-Based Simulation Framework to evaluate Urban Logistics Schemes

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Marco Schutten, *University of Twente, Netherlands*

Keywords: urban logistics, agent-based simulation, cooperation policies

Abstract

Inefficient urban freight transport has a negative impact on both livability and profit margins in the supply chain. Urban logistics schemes, consisting of one or multiple governmental policies and company initiatives, attempt to address these problems. However, successful schemes are difficult to realize due to the divergent objectives of the agents involved in urban logistics. Traditional optimization techniques fall short when evaluating schemes, as they do not capture the required change in behavior of autonomous agents. To properly evaluate schemes, we develop an agent-based simulation framework that assesses the interaction between five types of autonomous agents. Compared to existing studies in this field, we contribute by (i) explicitly including company-driven initiatives, and (ii) adopting a supply chain-wide perspective. We illustrate the working of our framework by testing a number of schemes on a virtual network.

Impact of Dwell Time on Vertical Transportation through Discrete Simulation in SIMIO

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Keywords: elevator, lift, management systems, intelligent objects, modeling, SIMIO, 3D simulation, case study

Abstract

This work has the objective of simulating an elevator system, using SIMIO software. First, two different approaches, and its implementation, will be explained and compared: Vehicle vs. Entity. After selecting which approach to follow, it will be used to conduct simulation experiments, with the purpose of evaluating the impact of the dwell time - time in which the elevator remains stopped, allowing for clients to enter - in the performance of the system. Particularly, analysing the impact on the total time - spent by clients from placing a call until reaching its destination - number of clients inside the system and waiting for the elevator, waiting time, elevator occupation and number of elevator trips. The analysis of the results indicates that, for the properties defined, the best time for the elevator to stay with its doors opened is around 10 seconds.

Improving Production Logistics Through Materials Flow Control and Lot Splitting

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Keywords: CONWIP, GKS, lot splitting, MTO, simulation

Abstract

The competitive advantage of make-to-order manufacturing companies is highly dependent on their capability to offer short delivery times and on-time deliveries. This calls for effective production and materials flow control – a core part of production logistics. This paper applies discrete simulation to study the delivery performance of a make-to-order manufacturing system configured as a general flow shop, when operated under two card-based material flow control mechanisms: CONWIP and GKS. The influence of two lot splitting strategies on the performance of these mechanisms is also evaluated. Results show that GKS clearly outperforms CONWIP and that splitting strategies have a positive impact on the performance of both mechanisms. GKS also showed to be particularly robust to the variation of the number of production authorisation cards used. This, together with the fact that the card-based mechanisms require little data handling and simplify production control, makes GKS attractive for practical application in make-to-order companies.

FA1: Container Terminals & Stowage II

Chair: Dario Pacino,

Friday 10:15-12:15, Room: 6.2.53

2D-Packing with an Application to Stowage in Roll-on Roll-off Liner Shipping

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Keywords: maritime transportation, 2D-packing, roll-on roll-off stowage

Abstract

Roll-on/Roll-off (RoRo) ships represent the primary source for transporting vehicles and other types of rolling material over long distances. In this paper we focus on operational decisions related to stowage of cargoes for a RoRo ship voyage visiting a given set of loading and unloading ports. By focusing on stowage on one deck on board the ship, this can be viewed as a special version of a 2-dimensional packing problem with a number of additional considerations, such as one wants to place vehicles that belong to the same shipment close to each other to ease the loading and unloading. Another important aspect of this problem is shifting, which means temporarily moving some vehicles to make an entry/exit route for the vehicles that are to be loaded/unloaded at the given port. We present several versions of a new mixed integer programming (MIP) formulation for the problem. Computational results show that the model provides good solutions on small-sized problem instances.

Towards Real-time Automated Stowage Planning - Optimizing Constraint Test Ordering

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Keywords: maritime logistics, stowage plans, optimization, heuristic algorithms, markov model

Abstract

Container stowage planning is a complex task in which multiple objectives have to be optimized while ensuring that the stowage rules as well as the safety and balance requirements are observed. Most algorithms for solving the problem are comprised of 2 parts: a container-location selection mechanism and a constraint evaluation engine. The former selects one or more container-location pairs for allocation iteratively and the latter evaluates whether the selected container-location pairs violate any of the constraints. We observe that, using the same selection mechanism, the order in which the constraints are evaluated can have significant impact on the overall efficiency. We propose the Sequential Sample Model (SSM) as an improvement over the existing Random Sample Model (RSM) for analysis of the problem. We present and evaluate several strategies in optimizing the constraint evaluation engine. We show how to achieve the optimal constraint ordering with respect to SSM. However, such ordering requires perfect information on the constraint tests which is impractical. We present alternative strategies and show empirically that their efficiencies are close to the optimum. Experiments show that, when compared to an arbitrary ordering, an average of 2.42 times speed up in the evaluation engine can be achieved.

Solving the Robust Container Pre-Marshalling Problem

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Keywords: container terminals, pre-marshalling, robust optimization, IDA*

Abstract

Container terminals across the world sort the containers in the stacks in their yard in a process called pre-marshalling to ensure their efficient retrieval for onward transport. The container pre-marshalling problem (CPMP) has mainly been considered from a deterministic perspective, with containers being assigned an exact exit time from the yard. However, exact exit times are rarely known, and most containers can at best be assigned a time interval in which they are expected to leave. We propose a method for solving the robust CPMP (RCPMP) to optimality that computes a relaxation of the robust problem and leverages this within a solution procedure for the deterministic CPMP. Our method outperforms the state-of-the-art approach on a dataset of 900 RCPMP instances, finding solutions in many cases in under a second.

Online and Offine Container Purchasing and Repositioning Problem

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Keywords: optimization and control for logistics, closed-loop supply chain, container management, planning tools, dynamic programming

Abstract

We study the management of containers in a logistic chain between a supplier and a manufacturer in a ramp-up scenario where the demand is stochastic and expected to increase. This paper extends our previous study with deterministic demand. We consider a periodic review system with T periods of R time steps. The supplier sends full containers at every step and receives empty containers every period. We consider positive lead times. To face demand increase, the manufacturer can purchase reusable containers at a setup cost while the supplier can buy single-use disposables. Using a dynamic programming framework we develop an online exact algorithm and an offline heuristic.

FA2: Routing II

Chair: Margarida Moz,

Friday 10:15-12:15, Room: 6.2.50

The Bi-Objective k-Dissimilar Vehicle Routing Problem

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Keywords: bi-objective, k-dissimilar vehicle routing problem, pareto set approximation

Abstract

This paper deals with the k-dissimilar vehicle routing problem in which a set of k-dissimilar alternatives for a capacitated vehicle routing problem has to be determined for a single instance. We investigate the tradeoff between minimizing the longest routing and maximizing the minimum dissimilarity between two routing alternatives when considering k routing alternatives of the CVRP. Since short vehicle routings tend to be similar to each other, a goal conflict arises. The developed heuristic approach aims to approximate the Pareto set with respect to this tradeoff using a dissimilarity metric based on a grid. The method is tested on benchmark instances of the CVRP and findings are reported.

A Heuristic Approach for the Determination of Routes for Parking Enforcement Officers

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Keywords: street parking enforcement, arc routing problem, heuristics

Abstract

EMEL – Empresa Municipal de Mobilidade e Estacionamento de Lisboa is a company owned by the Municipality of Lisbon who is in charge, amongst others, to manage and supervise on-street parking in the city. With the increasing demand for street parking in Lisbon, and with limited resources, EMEL has the challenge of allocating efficiently the existing resources, namely, the personnel assigned to on-street parking enforcement – the parking enforcement officers (PEO), that operate on foot. EMEL counts 115 PEOs' in average, and 52 300 street parking spots that need to be supervised.

Each PEO works on average 7.5 (seven and a half) hours a day, on working days, and street parking is supervised between 9 am and 7 pm. In order to grant a supervision of the whole period, PEOs' work is organized in shifts.

The PEO must ensure that the users of the street parking spots pay the correspondent fee, and also grant that they respect the existing parking rules established in legislation. When supervising streets, for each parked vehicle the PEO has to search for a ticket or a permit (residential, business, green), if there is no ticket or permit he must perform a digital search in order to verify if the user is paying with a fully digitalized process such as the online app (ePark). If there is any infringement, the PEO must issue a fine. He may also issue a fine if a vehicle is violating any rule of street parking legislation in non-paying locations, such as parking on the side walk or double parking.

The need of enforcement in each street is measured by a critical index named criticality, which was considered to vary with the hour of the day. Therefore, for each street we get ten different values for the criticality, one per hour of enforcement. The criticality of each street depends on the occupancy rate per hour, the type of fee applied on the area, the number of fines in the

previous N days, the hierarchy of the infringements associated with the fine and, finally, the time elapsed without supervision.

EMEL aims at determining an automatic procedure to construct daily routes for the PEOs', which currently, are defined by each PEOs' team supervisor on the basis of his personal awareness and experience.

The daily routes must satisfy the PEOs' work schedules, not allowing two or more PEOs in the same street at the same time, although street segments may be supervised more than once in the same shift on different hours. The objective is to maximize a function that represents the sum of criticality of the selected routes.

The problem is formulated in a network where nodes represent street intersections and arcs represent street segments between intersections. Some nodes are fixed as starting and ending points, which can be considered as depot where the PEO must begin and end the route. Each arc has a benefit (the criticality) associated, and a traversing time that consists in a crossing time without supervision. For some arcs an enforcement time is also considered if it is traversed with supervision.

This problem may be considered in the category of arc routing problems with profits. In this study, after collecting all the required data and designing the network, a constructive heuristic which returns a daily route for each PEO is proposed. Computational results from experiments carried out on real data-based instances will be presented and compared with solutions currently adopted.

Routes for Money Collection Operators

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Keywords: money collection operators, vehicle routing problem with profits,heuristics

Abstract

EMEL – Empresa Municipal de Mobilidade e Estacionamento de Lisboa is a municipality company in charge of the management of on-street and off-street parking spaces in the city of Lisbon. Paid parking not only raises awareness amongst car users making them properly park their vehicles and thus improving mobility and accessibility conditions in the city, but also saves tax payers money and time, a foundation that is itself crucial to the sustainability of a Smart City.

Beyond the constant development of its technology solutions, EMEL is constantly working towards a more efficient management of the existing resources. Presently, EMEL is in charge of 2000 parking meters and operates a small fleet of vehicles with limited capacity of safes to collect the parking fee. The collection of each parking meter usually involves the swap of the safe in the machine with an empty one.

The entire collections operation is performed in shifts per vehicle and per day, being that it does not cover all day. Collecting vehicles leave the base with pre-defined routes determined by the cash collection's operational supervisor, and try to execute the plan to completion. However, each time a vehicle reaches its capacity it then must return to base to unload the full/partially full safes and then go back to continuing its route and again collect as many safes as possible, repeating this procedure up to the end of its shift. The routes created by the chief responsible are based on his experience and empirical knowledge.

In the search of greater efficiency, namely in the creation of more efficient collection routes, EMEL started a partnership with ISEG, which resulted in a 6-months-traineeship. The aim is to combine the academic work with the company needs to obtain a useful tool (software) to suggest routes that, whilst allowing the collection of more money, will also reduce the money left on the street (thus reducing theft risk) at the end of each day.

The problem was interpreted as a Vehicle Routing Problem with Profits, as it is not required to service all nodes (the parking meters), but only those which grant a higher return (money),

taking into account the vehicles' capacity. The study was divided in four parts: Valuation model, Network design, Heuristic model and Interface/Software. Firstly a function was developed to predict the expected value in each parking meter (per hour) based on the knowledge of its past demand behaviour. Next, the basis working network was designed, connecting every pair of existing parking meters. Each node represents a parking meter and has an associated demand, which matches its expected value. Arcs representing the paths between two nodes have an associated travel time. The time was calculated based on the historical routes, for each hour of operation (7am-7pm), and its calibration is made according to each route's results.

Network data is connected to the company's server and may be updated if needed, from the database, each time the software is run. To obtain the routes, a constructive heuristic was programmed. The final part of this project was the design of a user-friendly interface to empower the collections chief responsible in using the software.

Using a set of KPI (key performance indicators), the routes obtained with the implemented models and software will be used to assess the quality of the current routes as well as to evaluate the developed heuristic.

Metaheuristics based on Decision Hierarchies for the Traveling Purchaser Problem

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Keywords: traveling purchaser problem, genetic algorithms, local search, heuristics, biased random key genetic algorithm

Abstract

Consider a depot, a set of markets and a list of items. The traveling purchaser problem (TPP) consists in determining one route that satisfies the following conditions: starts and ends at the depot; contains a subset of markets where it is possible to buy all the items in the list; and whose cost is minimal. The cost is the sum of the traveling cost and the purchasing cost. We know the cost of traveling between each pair of nodes (depot and markets) and also the cost of purchasing each item in each market where it is available. This variant of the TPP is called the unrestricted traveling purchaser problem (UTPP) and it was introduced in [7].

We present three different metaheuristics that are composed by a genetic algorithm (GA) and a local search procedure. While the local search is the same for all metaheuristics, the GAs are different since they are induced by the several hierarchic orderings that we can establish with the two components of the TPP: the route and the item acquisition. Two of the hierarchies have two levels of decision and one of them only has one. In a hierarchy with two levels of decision the chromosomes used in the genetic algorithm will encode the decision in the first level. Hierarchy 1 has as first decision the route thus, the chromosomes used are permutations. The item acquisition is determined afterwards. The first decision in hierarchy 2 is the item acquisition, so, we are going to use as chromosomes random keys. The route is determined posteriorly taking into consideration where the items are bought. Hierarchy 3 is the only one with one level of decision hence, we will use random keys to encode both the route and the item acquisition. The GA used in hierarchy 1 is a conventional one while in the other hierarchies we developed a biased random key genetic algorithm [4].

The local search algorithm requires as input a feasible solution of the UTPP. The first step of the local search is to obtain a minimal cover for the list of items with minimal cost followed by the removal of one random node. The next step is the addition of several markets in order to assure that we will obtain a feasible solution. The markets may be added according to several criterions that may favor either the route cost or the purchase cost or may be completely

random. Afterwards we will ensure, once again, that our solution is a minimal cover for the list of items. The local search algorithm is finalized with the application of an improvement heuristic on the route.

We used benchmark instances [9] to evaluate the quality of the proposed metaheuristics and to verify which is the hierarchy that performs better. There are two types of instances available for the UTPP, one with asymmetric traveling costs (see, e.g., [8]) and another with symmetric costs (see, e.g., [6]). Although the proposed methods were specially designed and tuned for the asymmetric version, we also applied them to the symmetric one. Concerning the asymmetric instances, the proposed metaheuristics are able to provide feasible solutions for instances which have not been solved in the literature (see [8], [5]). The results were very satisfactory since in 65 of 75 instances we obtained solutions with a percentage of gap lower than 1% within a very reasonable CPU time (maximum of 161 seconds). We solved two classes of symmetric instances - class 1 [2] and class 3 (see [1], [3]). In class 1 our metaheuristics were able to find new upper bounds for the optimal value of 14 out of 25 instances whose optimal value is not known. Even though in class 3 we were not able to obtain better results than the existing ones we were able to conclude that the quality of the results is influenced by the relation between the purchase cost and the route cost in the feasible solutions. The proposed methods provide better solutions when the biggest percentage of the solution value corresponds to the purchase cost.

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FB1: Synchromodality and Cross docking

Chair: Martijn Mes,

Friday 13:45-15:15, Room: 6.2.53

Service and Transfer Selection for Freights in a Synchromodal Network

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Keywords: synchromodal planning, anticipatory planning, intermodal transport, approximate dynamic programming

Abstract

We study the planning problem of selecting services and transfers in a synchromodal network to transport freights with different characteristics, over a multi-period horizon. The evolution of the network over time is determined by the decisions made, the schedule of the services, and the new freights that arrive each period. Although freights become known gradually over time, the planner has probabilistic knowledge about their arrival. Using this knowledge, the planner balances current and future costs at each period, with the objective of minimizing the total costs over the entire horizon. To model this stochastic and multi-period tradeoff, we propose a Markov Decision Process (MDP) model. To overcome the computational complexity of solving the MDP, we propose an Approximate Dynamic Programming (ADP) approach. Using different problem settings, we show that our look-ahead approach has significant benefits compared to a benchmark heuristic.

Towards Synchromodal Transport System Unification: Accomplishments and Challenges

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Keywords: synchromodal transport, intermodal transport, decision support systems, multi-modal freight transport

Abstract

With projected growth of international trade and cargo demand, the current infrastructural capacities are put under pressure resulting in congestion problems, safety issues, environmental concerns and decreasing reliability of services. Instruments used in the 'business as usual' approach are not sufficient in order to cope sustainably with the expanding market. Therefore, it is necessary to introduce innovative solutions that would support optimal integration of different transportation modes and their cost-effective use (EC, 2011). To achieve socio-economic and environmental sustainability, utilization of existing capacities and assets has become a key challenge for the transportation sector. This challenge has been recognized by many scholars, policy makers and practitioners leading to a substantial body of new concepts, models and initiatives. One of these concepts is synchromodal transport, which enables a better use of the infrastructure based on real time information.

In this paper we build an overview of what has already been achieved in the roadmap towards synchromodal transport and identify its important challenges. Building on the growing number of publications related to the evolution of intermodal transport (Caris et al., 2008, 2013; Macharis & Bontekoning, 2004; Mathisen & Hanssen, 2014; Reis, 2015; SteadieSeifi et al., 2014) we go a step further to bring the most recent developments into the contemporary academic sphere. Decisions within the synchromodal chain are more complex because, besides the inclusion of multiple actors and transport modes as it is in the intermodal chain, it adds extra real-time infrastructural and adaptive mode choice elements. The understanding of these interdependencies is thus crucial in order to provide a sufficient basis for decision-support-system models. The objective of this work is to review synchromodal papers containing the state-of-the-art models together with their methodologies, findings and interpretations which

have accumulated since the last reviews. Particular attention is given to case studies applied in the North-West Europe.

The review concludes with future research directions and introduces a structure of the SYnchronization Model for Belgian Inland Terminals (SYMBIT) that is being developed by the authors. The model is to support decisions of private and public decision makers with regard to the network usage, cargo allocation, route/mode selection and transport service design within the hinterland distribution.

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Metaheuristics for Integrated Cross-Dock Scheduling and Assignment

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Keywords: cross-docking scheduling, dock-door assignment, metaheuristics

Abstract

Cross-docks are facilities that allow consolidation of shipments from multiple origins into full truck load outflows with minimal storage of shipments within the facility [4, 5]. Shipments are stored within a cross-dock for less than a day and often for less than an hour. This leads to a high utilization rate for inbound and outbound trucks without storage costs at a cross-dock [4, 5].

Within the cross-docking environment, the assignments of trucks to dock doors and the scheduling of trucks for processing are two major decisions. During the assignment, assuming that the number of trucks (or clusters) equals the number of dock doors, trucks (or clusters) are assigned to dock doors, with the intention of minimizing the internal travel distance within the cross-dock [2, 7, 9, 12, 13]. Scheduling involves the sequencing of trucks for processing when the number of trucks is larger than the number of dock doors. In contrast to the assignment, internal travel distances within the cross-dock are not considered while scheduling. Schedules can be created with the objective of minimizing delayed shipments [4], lost shipments [10], makespan [1, 6, 14, 15], temporary storage [8], temporary storage and tardiness of outbound trucks [3], or maximizing throughput [11].

In smaller cross-docks with negligible internal travel distances, scheduling would suffice. However in larger cross-docks with a high truck-to-dock-door ratio, it could be beneficial to both schedule and assign trucks. Consequently, by scheduling and assigning, inbound and outbound truck pairs can be docked closer to each other which lead to lower internal traveling distances. The reduc-tion of internal travel distance can have significant benefits to the overall supply chain, since internal travel distance is a good proxy for labor cost and cycle time at a cross-dock [2].

Building on the existing work in [3], this work presents an ILP model which schedules and assigns both inbound and outbound trucks. The objective of the model is to reduce internal travel distances within the cross-dock and to avoid delays of outbound trucks.

Given the complexity of the integrated problem, as only the scheduling problem in NP hard [3], we further develop a metaheuristics to handle real sized problems. Results indicate that the metaheuristics produces close-to-optimal solutions for smaller instances and good solutions for larger instances within reasonable computation time. Experiments with instances based on the operation of a large Dutch retailer's cross-dock indicate that significant savings in travel distances can be made without compromising scheduling objectives. In some instances, internal travel distances could be reduced by as much as 37.5% compared to the base case according to which the industry partner currently operates its cross-dock without delaying outbound trucks.

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FB2: Supply Chain Management

Chair: Margarida Pato,

Friday 13:45-15:15, Room: 6.2.50

A Tri-Objective Strategic Model for a Food Bank Supply Chain

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Keywords: supply chain, sustainability, tri-objective model, integer programming

Abstract

Food waste has been identified as one of the most critical problems of today's society. According to the European Commission almost 90 million tons of food are wasted along the food supply chain every year in EU-28 alone, with associated costs estimated at 143 billion euros [1]. The fact that, concurrently, more than 120 million people, representing roughly a quarter of the European population, are at risk of poverty or social exclusion [2], among whom almost 50 million cannot guarantee a regular quality meal every other day [3], creates a paradox that has been at the core of the activities developed by food banks. However, in spite of the recognized importance of the role played by food banks at the economic, environmental and social levels, they have received little scientific attention so far. It is possible, nonetheless, to conceive the set of actors involved in the activities of food banks and the management of materials, information and capital required in a similar way as in a profit-oriented supply chain. In a food bank supply chain, products flow from suppliers (donors) to clients (non-profit organizations) via intermediate food bank facilities where they are processed.

The nature of the objective pursued by food banks highlights the sustainability theme that has been gaining increasing importance in modern managerial and logistics practices. Not only economic efficiency and efficacy are required, but also environmental objectives – expressed mainly by the minimization of food waste – and social objectives – providing the best food assistance possible to the population in need – are, by definition, at the very centre of the activities performed by a food bank supply chain. In this work, the supply chain of the "Federação Portuguesa de Bancos Alimentares" (FPBA) is studied. This supply chain currently comprises 18 facilities in mainland Portugal. These facilities differ considerably amongst themselves in terms of size and equipment. However, similar activities are performed at each facility, namely food products that would otherwise be wasted are received or collected from donors. These products are then sorted and selected at the food banks, where they are further assembled in daily and monthly baskets to be delivered to the benefiting organisations.

Products from donors may be collected by food banks, using their own fleet of vehicles, or may be directly delivered to the banks' facilities. Each of these donors is defined by its location and amount of product(s) available for donation. Other donors provide support in the form of money that is used to purchase any type of product needed. Food banks are characterized by their location as well as storage and transportation capacities. At each facility, up to three families of food products may be stored (dry, fresh and cold products), each type demanding specific temperature conditions.

We address the strategic (re)design of the food bank network of FPBA over a multi-period planning horizon. Given the existing banks' facilities and considering a set of potential sites for locating new food banks, at each time period it must be decided which existing banks should be closed and in which locations new food banks should be established. In addition, capacities for storage and transportation must be selected from a finite set of available capacity levels and types. Facility location and capacity acquisition decisions are constrained by the budget available in each time period. The flow of products through the network is also to be planned. A further distinctive feature of our problem is that products may flow between different food banks. Moreover, each benefiting organization can be served by at most one food bank. Since supply is often less than demand, some organizations may experience shortages. The network structure will be shaped according to economic (operating and investment costs), environmental (food waste and CO2-gas emissions) and social objectives (number of benefiting organisations served, balance of product distribution among them and distance between those organisations and the banks they are assigned to). The resulting tri-objective multi-period optimization problem is modelled as a mixed-integer linear program. A study is performed on the current network of FPBA by determining the lexicographic optimal solutions with a general-purpose solver. Useful managerial insights are derived from the case study.

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Design of Multi-Echelon Supply Chain Networks under Outsourcing Opportunities

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Keywords: logistics network design, transportation mode selection, product outsourcing, mixed integer linear programming

Abstract

We address the problem of designing a multi-echelon supply chain network comprising suppliers, production plants, warehouses and customer zones. Strategic decisions include opening new plants and warehouses at candidate sites and selecting their capacities from a finite set of available capacity levels.

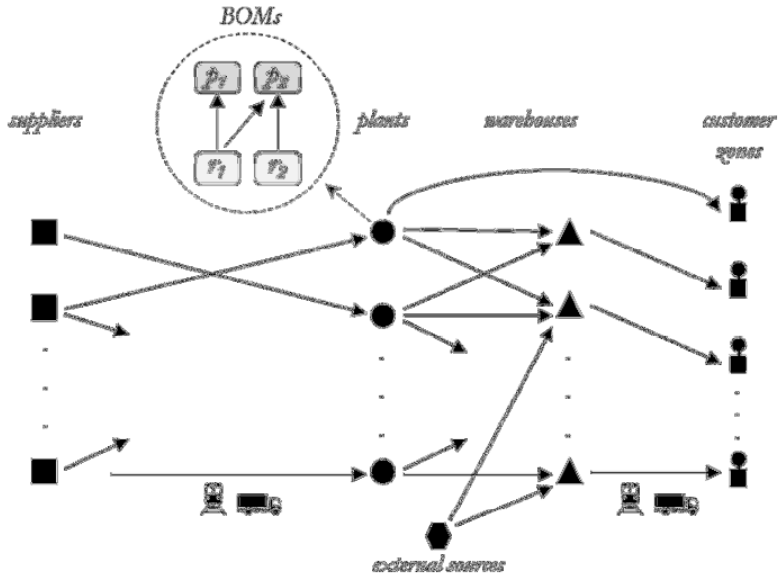

Figure 1: General structure of the supply chain network.

In addition, the operation of the supply chain network is also subject to decisions involving supplier selection, procurement of raw materials as well as production and distribution of end products. Shipments between facilities and to customer zones can be performed using different transportation modes. Rail and road freight transport are examples of possible options. Each

option is associated with a minimum shipment quantity, a maximum transportation capacity and a variable cost. Multiple types of end products are manufactured at plants by processing specific raw materials according to given bills of materials (BOMs). Different classes of raw materials are considered. One of them represents minor components that are required to manufacture all types of end products. At each potential plant location, some production resources may only be available to manufacture specific products (e.g. a machine dedicated to a given item). Global capacity limits are imposed at plants and warehouse locations. A new plant and a new warehouse can only be operating provided that a minimum capacity utilization level is achieved. Furthermore, a strategic choice between in-house manufacturing, outsourcing or a mixed approach is also to be made. An upper bound on the quantity of an end product that can be purchased from an external source is imposed. Outsourced products are consolidated at warehouses. Although product outsourcing incurs higher costs than in-house manufacturing, this option may be attractive when the cost of establishing a new facility to process given end items is higher than the cost of purchasing them. A further distinctive feature of our problem is that each customer zone must be served by a single facility (either a plant or a warehouse). Many companies strongly prefer single-sourcing deliveries as they make the management of the supply chain considerably simpler. Direct shipments from a plant to a customer zone are only permitted if at least a given quantity is distributed to the customer zone. Such a delivery scheme reduces transportation costs for large quantities. In addition, each raw material must be purchased from a single supplier by an operating plant. However, different raw materials may be procured from multiple suppliers by the same plant. This feature overcomes the disadvantages of single-supplier dependency. Fixed costs for location and capacity choices for plants and warehouses are considered. In addition, variable costs are associated with procurement, production, transportation and outsourcing. We propose a mixed-integer linear programming model to determine the least cost network configuration that satisfies all demand requirements. By integrating various strategic and tactical features of practical relevance into a single model, our formulation generalizes several existing supply chain network design models. Moreover, the new model captures different types of network structures and tailored distribution strategies. Additional inequalities are derived in an attempt to strengthen the linear relaxation bound and to improve the performance of the model. To gain insight into how challenging it is to solve the problem at hand, a computational study is performed with randomly generated instances and using a general-purpose solver. Useful insights are derived from analysing the impact of different business strategies on various segments of the supply chain network.

Distribution of Agricultural Products in a Short Distribution Channel. A Case Study in the Peninsula of Setúbal.

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Keywords: pickup and delivery vehicle routing problem, short distribution agricultural channels heuristics, mixed integer linear programming

Abstract

The aim of this work is to optimize the distribution and transportation of agricultural products from farmers directly to restaurants and canteens in the region of Setubal, Portugal. The successful establishment of such a short distribution channel would provide several social, economic and environmental benefits. It would allow farmers to have access to new markets and new sources of income, selling products that currently are not sold, and that otherwise would be wasted. Customers, on the other hand, would have access to local products of quality, hopefully at competitive prices, delivered at their own places. The community would benefit from the quality of these products and also from a greater sense of trust between customers and farmers, contributing thus for the initiative's social responsibility and economic viability.

Environmental benefits would result essentially from short distances traveled by food and the maintenance of the rural landscape in the periphery of the urban area. As transportation costs can be a significant part of a business overall costs, they can make products more expensive and therefore less competitive. It is then advisable to plan the food distribution in a rational manner in order to contribute for the initiative's economic viability. The distribution planning problem encompasses the assignment of production to demand and the determination of the distribution routes. The first problem takes into account that some products are storable and thus there is, in a certain way, stock management. With respect to the second problem, one considered two types of distribution routes: pickup and delivery routes, in which products are transported from farmers or the warehouse to customers and, whenever there is some available capacity in the vehicles, storable production to the warehouse; pickup routes in which storable products are brought from farmers to the warehouse. Production to the warehouse (stock management) is assigned at the beginning of the week, while the routes for transporting

such production are determined at the end of the week (some adjustments are necessary because some of this production have been picked up during the week). The assignment of production from farmers or warehouse to customers' demand and the determination of the routes to pickup and deliver this production is done weekly on a daily basis.

Concerning the optimization methods, two different approaches were considered in order to address the distribution planning problem. First, a mixed integer linear programming (MILP) model is proposed where both problems, the assignment of production to customers' demand and the determination of the pickup and delivery routes, are solved simultaneously as an "integrated" problem. In the "unaggregated" approach, those problems are addressed separately and they are both solved using heuristics. Stock management, the assignment of production to the warehouse and the determination of the pickup routes for storable products are only solved separately. The assignment problem is solved by the use of a heuristic which assigns production to customers' demand, taking into account customers' preferences and equity criteria. After assigning production to customers' demand, this is, after determining which farmers will supply each customer with which products and the corresponding quantities it is necessary to obtain the pickup and delivery distribution routes. A two stage heuristic was implemented, in which the first phase is a constructive heuristic based on Clarke and Wright Savings Algorithm (CWSA) for the classical vehicle routing problem. Two different versions are presented: a parallel and a criterion-based version. This constructive phase is followed by an improvement phase where two local search procedures are performed consecutively, both guided by a simulated annealing algorithm. These local search procedures attempt to swap nodes within an established route in order to improve upon the solution given by the constructive procedure.

Computations were performed on a desktop computer with an Intel Core 2 – 2.13 GHz processor and 2 GB RAM regarding the "integrated" approach and a laptop computer with a Dual Core 2 – 2 GHz processor and 4 GB RAM for the "unaggregated" approach. Cplex 12.5 was used as the MIP solver. Computational results showed that the "unaggregated" approach was better suited than the "integrated" approach. For the case study, that approach provided a better solution and spent much less computational time.

FC1: Intermodal and Maritime Transportation

Chair: Christine Tawfik,

Friday 15:45-16:45, Room: 6.2.53

A Bilevel Design and Pricing Model for an Intermodal Service Network

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Keywords: intermodal transport, bilevel programming, stackelberg games, logistics costs, discrete choice analysis, freight choice modeling

Abstract

In recent years, intermodal freight transport has claimed a rightful position among policy makers and researchers as a sustainable and ecological alternative. Furthermore, when broadly adopted, it provides significant opportunities to generate economies of scale. These two previous reasons have hitherto fueled a wide interest, manifested in governmental incentives and target policies, to stimulate the position of intermodal transport in the EU market. Nevertheless, both the quality of its services and their corresponding prices have so far failed to attract the desired customer levels; a concern supported by the recent EU modal split figures.

In this work, we consider the problem of simultaneously designing the intermodal services to operate during a medium-term planning horizon and determining their associated tarifs as perceived by the shipper firms. The decisions are tackled from the perspective of a single intermodal operator/service provider, while accounting for the shippers' choices and assuming no service nor price change reaction from the competition, represented in all-road services during the process. In more formal terms, a bilevel program is defined as to depict the hierarchical case of decision-making, akin to the concept of a sequential Stackelberg game in the field of game theory. To the extent of our knowledge, joint service network design and pricing problems are noticeably underinvestigated in the literature, much less in the domain of intermodal transport. Moreover, the bilevel programming framework, though proven adequate in similar hierarchical and non-cooperative decision schemes, is still a scarcely utilized concept in intermodal transport planning issues.

Throughout this paper, we essentially provide modeling insights of the bilevel problem in question. More precisely, at the upper level, the intermodal operator (the leader), in the quest of profit maximization, has the precedence of selecting the operating frequencies of their freight services and their corresponding prices. While at the lower level, the shippers (the followers) presented with feasible itineraries as sequences of the leader's services, decide on

the volumes of their demands to send over these itineraries and the available trucking alternative. Due to the particular structure of intermodal networks, a path-based formulation is considered, incorporating three transport modes: road, rail and inland waterways. At a pre-processing stage, a procedure is implemented to generate geographically feasible itineraries and eliminate those that are not conform to intermodal specific paths' standards. Additionally, we shed light on a problematic type of constraints; the service capacity constraints that involve variables from both the upper and the lower level, an issue particularly highlighted in previously related works [1, 2]. We discuss different alternatives for their position at the upper or the lower level, formulation and the implications of each on the problem's complexity and solutions.

In order to increase the realism of our study, the lower level problem is expressed based on an idea to combine discrete choice methods with the minimization of total logistics costs; a perspective defended in [3] as analogous to utility maximization modeling in passenger traffic. Normative approaches provided by traditional cost models repetitively fall short of coinciding with the shippers' actual choices, principally due to the lack of significant information and the nonuniform shippers' perception of the service quality. We propose a statistical approach to estimate the missing information and the importance of the cost components. We consider elements that embody the shippers' actual expenses and interpretation of the level of service. The analysis is to be based on revealed preference data, elicited through a survey among prospective intermodal clients. We believe this would be the first time to integrate a choice model in the reaction of the followers in bilevel pricing and design models.

In the next stages, we intend to conduct computational experiments for a proof of concepts, using reasonably designed instances. The innate complexity of bilevel programs already suggests the need to devise solution and decomposition algorithms that exploit the particular problem's structure, in order to be able to invoke it on large and real-life inputs. The underlying research in this work is conducted in accordance with the project BRAIN-TRAINS, concerned with the future of rail freight intermodality in Belgium and Europe, and funded by the Federal Science Policy according to the contract n. BR/132/A4/BRAIN-TRAINS.

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Using Fourier-Motzkin Elimination to Produce Efficient Cargomix Models for Revenue Management

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Keywords: maritime applications, uptake management, capacity management, decision support systems, projection, polyhedral combinatorics.

Abstract

In the daily operations of a liner shipping company, the service network and fleet are constant, and it is therefore important to utilize the capacity of the fleet in the given network as much as possible to gain the largest profit. The capacity of a service network is given by the capacities of the utilized ships, and at present time, this cargo capacity of a container ship is usually given by three constant values: the volume capacity, the weight capacity and the reefer capacity.

However, this very simple capacity model ignores how the containers are stowed on the ships, which can lead to substantial erroneous assumptions on the stowage ability and in the ensuing conclusions about the effects on the capacity utilization and hence the revenue.

On the other hand, cargomix models exist that express how many containers of various types - defined by weight class, height and reefer-property - it is possible to stow in each bay of a container vessel without breaking i.a. seaworthiness, capacities and stacking rules. These models can therefore be used to calculate a ship's capacity as a function of the cargo composition. However, the models are often very large, which prohibits them from use as sub-components in optimization systems for revenue management. The reason is that the models include information about where the cargo is stowed, whereas the dependencies between the mere number of each type is sufficient for revenue management.

To use these cargomix models for revenue management it is therefore necessary to abstract the location information away. Theoretically, this can be achieved by use of the Fourier-Motzkin Elimination method (FME). At each step in this algorithm, a variable (location information) is eliminated whereby the number of inequalities potentially are squared, causing the intermediary systems as well as the running time to potentially become extremely large.

Although redundant inequalities can be removed using e.g. CPLEX, this is also expensive timewise, and hence FME is often viewed as unfit for use.

In our work, we use a hierarchically decomposition of the models and a parallelized version of FME with redundancy removal to handle the high combinatorial complexity of the algorithm. Our results so far show that FME is a promising approach for computing abstract cargomix models with a small resulting size that are fit for use in revenue management.

FC2: Decision Support Tools

Chair: Mario Ruthmair,

Friday 15:45-16:45, Room: 6.2.50

Optimizing Checkpoints for Arrival Time Prediction

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Mario Ruthmair, *University of Vienna, Austria*

Keywords: mixed integer linear program, optimal placement, pareto optimal solution, arrival time prediction, travel time

Abstract

To improve processes at freight trans-ship ent centers (FTSCs), it is essential to know when vehicles will arrive in order to schedule and coordinate activities and to optimally employ manpower and machines. Therefore, in this study we describe the optimization of checkpoint locations in order to accurately estimate the arrival of approaching vehicles. In multi-modal FTSCs arrival time estimation is performed differently for each mode of transport. For example, travel times on inland waterways are mainly determined by properties of the ship (e.g., width or draught) which can be used to predict arrival time at the harbour (cf. [1]).

In contrast, arrival times for road vehicles may be estimated from various sources providing travel times (e.g., Google Maps). However, these systems mostly aim at predicting travel times of passenger cars and are not suitable for trucks because of different speed limits. Moreover, to estimate arrival times it is mandatory to know the location of the truck on its way to the FTSC. If the vehicle is equipped with GPS and positions are transmitted to an operator, the travel time to the FTSC can be continuously estimated. However, if such a system is not available to the operator of an FTSC, a solution could be to automatically detect trucks at checkpoints along the road and subsequently estimate arrival times. For this purpose an automatic number plate recognition (ANPR) system may be used, which allows to reliably detect trucks according to their number plate (cf. [2]). Since ANPR systems are cost-intensive, only a limited number of devices can be installed.

In order to optimize the planning abilities in the FTSC, the objective of this work is to formulate and solve a multi-objective optimization problem to find checkpoint locations for trucks with the following (partly contradicting) objectives: Minimize the number of checkpoints, maximize the average residual travel time from checkpoint to FTSC, and maximize the average certainty of residual travel times. To save costs a minimum number of checkpoints is desirable. The

residual travel time is maximized in order to enable the operator of a FTSC a large time frame to schedule activities. But this time frame should be reliable, and that is why certainty of residual travel time is maximised. As a side constraint a given minimal detection rate of approaching trucks has to be satisfied.

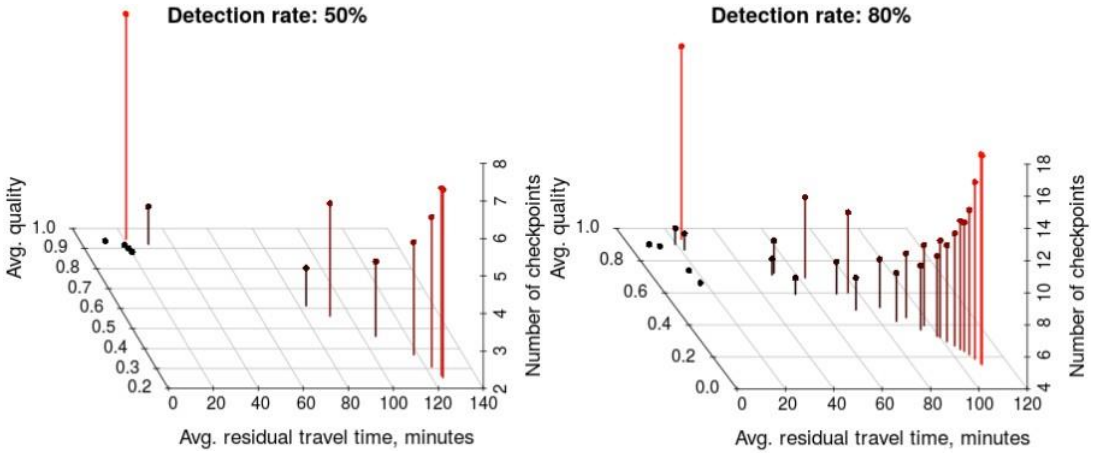

Figure 1: Pareto-optimal solutions for 50% (left) and 80% (right) detection rate. The color gradient from black (low) to red (high) refers to the number of checkpoints.

The detection rate is defined as the ratio between the sum of all detected trucks at the checkpoints and the total number of trucks heading for the FTSC. The certainty of residual travel times is based on the buffer time index (BTI, cf. [5]), which is the ratio between average delay and expected travel time. The BTI is positive and unlimited with low values representing a high certainty in travel time. The certainty of the BTI itself depends on the number of underlying travel time observations. Therefore, we combine the BTI and the number of observations and scale it to the interval [0,1]. We call this indicator 'quality' with 1 as best and 0 as worst possible value. The average travel time from a checkpoint to the destination (FTSC) is estimated from historic truck data. The goal is to find a minimal number of checkpoints to detect trucks, from which the average residual travel time to the FTSC and the corresponding average quality is maximal. Each link of the underlying road network is a potential checkpoint location.

The optimization problem is modeled as a mixed integer linear program [4], applied to truck movement data, and solved using the CPLEX framework embedded in a variant of the epsilon-constraint method [3]. We use binary variables to indicate if a link of the road network is selected for a checkpoint. Although a trip can pass several checkpoints it accounts only once to the sum of detected trips. It can be easily seen that the three types of objectives and the constraint are partially contradicting, so we consider a tri-objective optimization approach to obtain a set of pareto-optimal solutions which can be handed over to the decision-maker.

Figure 1 shows that average residual travel time can be mainly increased if a lower quality is accepted and vice versa. Trucks come from several sources in the surrounding area and use a variety of different roads on their way to the FTSC. As they approach their destination, residual travel time decreases as well as the number of possible road links to use. This results in a lower number of checkpoints to be installed in order to achieve the same detection rate. It can be easily seen in the figure that an increased number of checkpoints corresponds to an increased average residual travel time. This relation is not obvious with respect to average quality and number of checkpoints. In Figure 1 we can also see that for a certain range of average residual

travel time (left plot: 30-80 minutes, right plot: 20-50 minutes) no pareto-optimal solution exits, which is due to peculiarities of the investigated road network. The solutions with a very low number of checkpoints (approximately two in the left plot and four in the right plot in Figure 1) exhibit a small average residual travel time and very high average quality (0:9). However, the highest average quality slightly above 0.9 is only achievable with a large number of checkpoints. This indicates that the number of checkpoints is rather sensitive to average quality and a high average quality will most probably result in a costly solution. In other words, large amounts of installation costs can be saved if small reductions in average quality are accepted.

Based on the presentation of the pareto-optimal front a decision maker can choose a preferred setting e.g., based on carefully weighting the gain of increasing average residual travel time against the resulting loss in average prediction quality or deciding if additional checkpoints should be used to increase quality or residual travel time.

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LORE, a Decision Support Tool for Location, Routing and Location-Routing Problems

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Abstract

LOcation Routing Exploration (LORE) is a decision support tool for addressing location, routing and location-routing problems. In this paper the LORE tool will be presented, and its main characteristics addressed. Among the main features of the tool is the ability to support a variety of problems currently being studied in the location and routing literature (due to the proposed data structure), and the graphical user interface (GUI). The data structure will be presented by providing an explanation on how it can support related problems. The GUI main goal is not only to aid the solution-finding process but also to foster greater insight into the problem(s) at hand. To that extent, the GUI, developed to fit the target user's profile and intended tasks, is presented, namely data input and visualization features.