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Scheduling and Planning the Outbound Baggage Process at International Airports

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Abstract

The scheduling of outbound baggage at international airports is a challenging task in the airport industry. The issue is to control the incoming baggage flow in order to balance the workload over the system. The resource consumption of the different activities, which have to be scheduled, are depending on the arrival process of the baggage. Because of high complexity we suggest a decomposition heuristic to tackle this problem.

Keywords - Outbound baggage, Scheduling Problem, Assignment Problem, RCPSP, Workload balancing

I. INTRODUCTION

We consider the scheduling of outbound baggage at hub airports. For each flight the baggage arrives through the checkins as well as by feeding flights. Let \mathcal{F} be the set of flights and $\mathcal{T} := \{0, \dots, T\}$ be the discrete planning horizon. Then we have for each flight $i \in \mathcal{F}$ and $t = 0, \dots, T - 1$ an arrival process $A_{i,t}$ which gives the amount of baggage arriving during time period $[t, t + 1]$. The incoming baggage is eventually sent to a circulation, a circles shaped conveyor belt where the baggage is loaded into bag carts. After loading, the bag carts are transported to the outbound plane. Circulations are scarce resources and we address their efficient use by proper assignment and scheduling of the baggage handling to flights. Central decisions are the circulation assigned to a flight, the start time the circulation is processing the baggage of the flight and the release time of baggage in the central storage system to the assigned circulation.

Since baggage might arrive quite some time before the flight leaves, the baggage cannot be directly routed to a circulation but is sent to a central storage system with capacity κ instead. As soon as a circulation is assigned to a flight, incoming baggage will be sent to this circulation and not to the central storage anymore. However, the baggage which has accumulated in the central storage so far has also to be sent to the circulation. Hence, it has to be decided at what time the baggage of the flight in the central storage is released to the circulation. We denote by $S_i^H \in [ES_i, LS_i]$ the time a circulation starts processing a flight where ES_i and LS_i give the earliest and latest processing time, respectively. $S_i^D \in [S_i^H, S_i^E - p_i^D]$ denotes the time the baggage of flight i in the storage is released to the circulation where S_i^E is the deadline for the baggage handling of flight i and p_i^D denotes the duration required to release the baggage of flight i from the central storage to the circulation. Duration p_i^D depends on the transfer rate ρ which gives the number of baggage units transferred per period.

Let us have a more detailed look at the circulations (see Figure 1). The conveyor belt of circulation $c \in \mathcal{C}$ has a capacity of κ_c baggage units. Obviously, κ_c depends on the length of the conveyor belt. Circulation c is made up of W_c working stations. At each working station $u = 1, \dots, W_c$ baggage can be unloaded from the conveyor belt to the bag carts with a depletion rate of α units per period. Each working station u at circulation c consists of $P_{c,u}$ parking spaces. The number of all parking spaces of circulation c is $P_c := \sum_{u=1}^{W_c} P_{c,u}$. One parking space can accommodate one bag cart. The number of bag carts required for flight $i \in \mathcal{F}$ is denoted by ζ_i . A working station can only be assigned to a flight if at least one bag cart is placed on a corresponding parking place. Furthermore, in order to carry the bag carts with a towing vehicle to the aircraft, the bag carts on the parking places have to be sequentially ordered on each side of the circulation. Figure 1 shows a feasible assignment of 3 flights to a circulation, with 4 working stations (WS) and 5 parking spaces per working station.

II. DECOMPOSITION PROCEDURE

The problem can be modelled as a generalisation of the resource-constrained project scheduling problem (RCPSP) with the storage and conveyor belt of the circulations as cumulative resources, the baggage arriving process of each flight as replenishing activity, the start of the handling process at the circulation as a depleting activity and the release activity of the storage as, both, replenishing and depleting (see [1] and [2] for details of the general modelling concepts). Note that the depletion rate of the handling process at the circulation depends on the number of workstations assigned to a flight.

A general mixed-integer program (MIP) with on/off variables (e.g. [3]) is proposed in [4]. We used the state-of-the-art MIP solver CPLEX to solve this MIP formulation and compared the solution with the method currently used at Munich Airport.

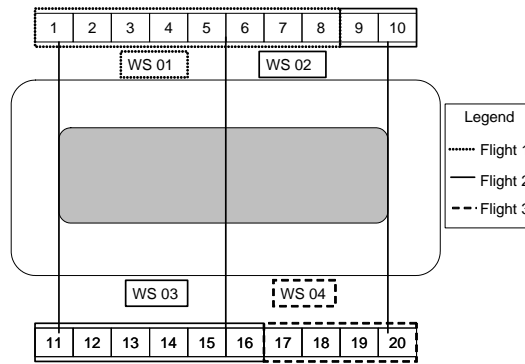


Fig. 1. Feasible assignment of 3 flights to 4 working stations of a circulation.

For the assignment problem they use a system of rules whereas the scheduling problem follows a rule of thumb. For our experiments, we employed a test instance of 4 flights, one circulation with 4 working stations and 10 parking places, and a time horizon of 80. It turned out, that we could improve the workload with our MIP formulation up to 60%. The computing time for the instance was about 180 sec to get an optimal solution. However, if we double the number of flights and working stations we already got computing times of up to 1 hour if we solve the problem to optimality. A real instance with up to 370 flights, 22 circulations with about 4 working station and 10 parking spaces per circulation seems to be intractable. Our experiments and the fact that the problem of finding a balanced workload over all circulations is NP-hard (cf. Lemma 1) give the need of heuristic procedures. We present a decomposition heuristic to get a balanced workload over all circulations \mathcal{C} . For

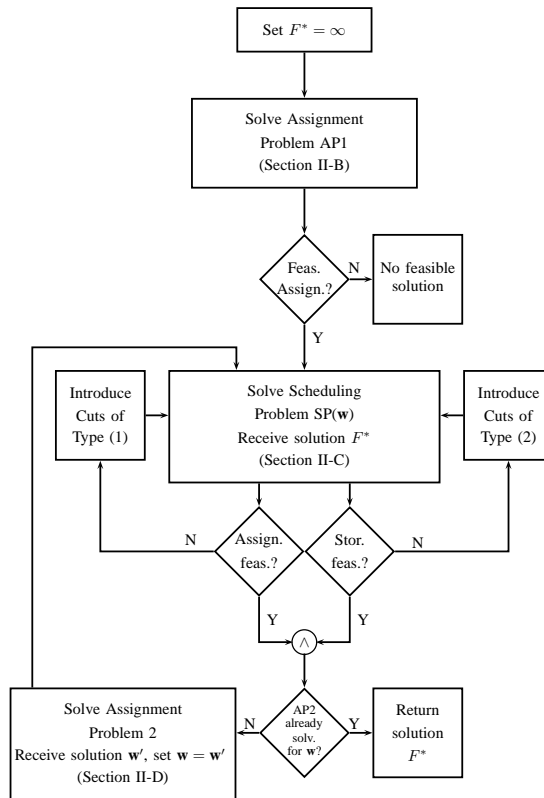


Fig. 2. Scheme of the decomposition heuristic.

the decomposition we separate the problem into a scheduling problem (see Section II-C) and two assignment problems (see Section II-B and II-D). The connection between these problems is shown in figure 2.

In the first step we assign flights to circulations, where we assume that the starting time of the storage depletion is equal to the starting time of the baggage handling (see section II-C). The objective of the assignment problem is to minimize the maximal workload of each circulation. Next, we schedule the starting times of the baggage handling and starting times of the storage depletion for a given assignment vector \mathbf{w} of working stations to flights. The objective is to minimize the maximal workload for the given assignment of flights to circulations. If the schedule violates the storage capacity or the restriction given by the received assignment in step one we introduce cuts. Afterwards we solve the scheduling problem again. Finally, a feasible schedule in terms of the storage capacity and the given assignment is received (see section II-C1). In the second assignment problem the working stations are assigned to the flights in order to minimize the maximal workload of each circulation. It turns out that we can formulate this problem as a minimum cost flow problem (cf. [5]). With the received assignment \mathbf{w}' of working stations to flights we optimize scheduling problem again to smooth the maximal workload again.

A. Definitions

Parameters $\check{\xi}_{i,c}$ and $\hat{\xi}_{i,c}$ denote the minimal and maximal required number of working stations, which can be assigned to flight $i \in \mathcal{F}$ on circulation $c \in \mathcal{C}$, respectively. The number of assigned working stations to flight i will be denoted by $w_i \in \mathbb{N}$. The assignment vector of working stations to the different flights is defined by $\mathbf{w} := (w_i)_{i \in \mathcal{F}}$. For each flight $i \in \mathcal{F}$ we set the minimal required number of working stations as $w_i^{\min} := \min_{c \in \mathcal{C}} \{\check{\xi}_{i,c}\}$.

If we start the baggage handling of flight i at time $S_i^H \in [ES_i, LS_i]$, it takes $p_i^D(S_i^H) = \left(\sum_{z=S_i^S}^{S_i^H-1} A_{i,z} \right) / \rho$ time units to deplete all pieces of baggage stored for flight i . We set $rest_i(S_i^H) := \left(\sum_{z=S_i^S}^{S_i^H-1} A_{i,z} \right) \bmod \rho$.

In the following definition we use indicator function $\mathbb{1}_A(t)$ with $\mathbb{1}_A(t) = 1$ if $t \in A$ and 0 else.

Definition 1: Let $S_i^H \in [ES_i, LS_i]$ and $S_i^D \in [ES_i, S_i^E - p_i^D(S_i^H)]$. For each $i \in \mathcal{F}$ define:

(i) *Workload function*

$$\begin{aligned} T_{i,w_i}(S_i^H, S_i^D, t) &:= \mathbb{1}_{[S_i^H, S_i^E]}(t) \cdot (T_{i,w_i}(S_i^H, S_i^D, t-1) \\ &+ A_{i,t} + \mathbb{1}_{[S_i^D, S_i^D + \lfloor p_i^D(S_i^H) \rfloor]}(t) \cdot \rho \\ &+ \mathbb{1}_{]S_i^D + \lfloor p_i^D(S_i^H) \rfloor, S_i^D + p_i^D(S_i^H)}(t) \cdot rest_i(S_i^H) - w_i \cdot \alpha)^+ \end{aligned}$$

gives the amount of baggage on a circulation $c \in \mathcal{C}$ at time t by assuming a working rate of $w_i \cdot \alpha$.

(ii) *Storage function*

$$\begin{aligned} G_i(S_i^H, S_i^D, t) &:= \left(\sum_{z=S_i^S}^{\min\{t, S_i^H-1\}} A_{i,z} \right) \\ &- \min \{ (t - S_i^D)^+, p_i^D(S_i^H) \} \cdot \rho \end{aligned}$$

gives the amount of baggage stored for flight i at time $t \in \mathcal{T}$.

B. Assignment Problem 1

In the first step of the decomposition heuristic we assign each flight $i \in \mathcal{F}$ to a circulation $c \in \mathcal{C}$ such that the maximal workload will be minimized. Assignment problem 1 (AP1) will be called feasible if the an assignment of flights to circulations doesn't violate the capacity of the parking places and working stations of each circulation $c \in \mathcal{C}$ and the storage capacity.

In AP1 each flight $i \in \mathcal{F}$ needs only his minimal number of required working stations w_i^{\min} . The start times of the storage depletion S_i^D is equal to the start time of the baggage handling S_i^H for all flight $i \in \mathcal{F}$, e.g. $S_i := S_i^H = S_i^D$. AP1 can now be stated as follows:

$$\text{minimize } \max_{c \in \mathcal{C}, t \in \mathcal{T}} \frac{\sum_{i \in \mathcal{F}} T_{i,w_i^{\min}}(S_i, S_i, t) \cdot b_{i,c}}{\kappa_c} \quad (1)$$

subject to

$$ES_i \leq S_i \leq LS_i \quad \forall i \in \mathcal{F} \quad (2)$$

$$\sum_{c \in \mathcal{C}} b_{i,c} = 1 \quad \forall i \in \mathcal{F} \quad (3)$$

$$\sum_{i \in \mathcal{F}: S_i \leq t \leq S_i^E} \varsigma_i \cdot b_{i,c} \leq P_c \quad \forall c \in \mathcal{C} \quad (4)$$

$$\forall t \in \mathcal{T}$$

$$\sum_{i \in \mathcal{F}: S_i \leq t \leq S_i^E} \check{\xi}_{i,c} \cdot b_{i,c} \leq W_c \quad \forall c \in \mathcal{C} \quad (5)$$

$$\forall t \in \mathcal{T} \quad (6)$$

$$\sum_{i \in \mathcal{F}: S_i^S \leq t \leq S_i^E} G_i(S_i, S_i, t) \leq \kappa \quad \forall t \in \mathcal{T} \quad (6)$$

$$b_{i,c} \in \{0, 1\} \quad \forall i \in \mathcal{F} \quad (7)$$

$$\forall c \in \mathcal{C} \quad (8)$$

$$S_i \in \mathbb{N} \quad \forall i \in \mathcal{F}. \quad (8)$$

It is not hard to show that the BIN-PACKING PROBLEM can be reduced to the problem of finding a feasible solution for the restrictions (1) to (8) in polynomial time. So we can hold the following Lemma.

Lemma 1: Problem (1) to (8) is NP-complete.

Despite API is NP-hard we can decompose API by means of Danzig-Wolfe into two subproblems: A set covering problem and a resource-constraint project scheduling problem (. These subproblems are also NP-hard but there are heuristics giving good approximations of the optimal solution and also exact algorithm in the literature having good computing times even for big instances (see [6], [7], [8]). The *feasible assignment vector* of problem API corresponding to the optimal solution will be denoted by vector $\mathbf{b} = (b_i)_{i \in \mathcal{F}}$ with $b_i = c$ if flight $i \in \mathcal{F}$ is assigned to circulation $c \in \mathcal{C}$. Note, if we can't find a feasible solution for API there will be no feasible solution for complete problem.

In the following $\mathcal{V}_c \subset \mathcal{F}$ represents the subset of flights which are handled on circulation $c \in \mathcal{C}$. On set \mathcal{V}_c we define relation \preceq with $i \preceq j$ for $i, j \in \mathcal{V}_c$ iff $S_i^E \leq S_j^E$. The linear order will be denoted by $\mathcal{O}_c := (\mathcal{V}_c, \preceq)$.

C. Scheduling Problem

Once we have got a feasible assignment vector \mathbf{b} for API we solve scheduling problem (SP(\mathbf{b}, \mathbf{w})) minimizing the maximal workload on each circulation $c \in \mathcal{C}$ by given assignment vector \mathbf{w} and given assignment . If we solve SP(\mathbf{b}, \mathbf{w}) for the first time, we set $w_i = w_i^{min}$ for each $i \in \mathcal{V}_c$ and $c \in \mathcal{C}$.

$$\text{minimize } \max_{c \in \mathcal{C}, t \in \mathcal{T}} \left\{ \frac{\sum_{i \in \mathcal{V}_c} \sum_{\nu = ES_i}^{LS_i} \sum_{z = \nu}^{S_i^E - p_i^D(S_i^H)} T_{i, w_i}(\nu, z, t) \cdot x_{i, \nu, z}}{\kappa_c} \right\} \quad (9)$$

subject to

$$\sum_{\nu = ES_i}^{LS_i} \sum_{z = \nu}^{S_i^E - p_i^D(S_i^H)} x_{i, \nu, z} = 1 \quad \forall c \in \mathcal{C} \quad (10)$$

$$\forall i \in \mathcal{V}_c \quad (11)$$

$$\forall i \in \mathcal{F}$$

$$\forall t_1 \in [ES_i, LS_i]$$

$$\forall t_2 \in [t_1, S_i^E - p_i^D(t_1)].$$

Given starting time vector of the baggage handling $\mathbf{S}^H := (S_1^H, \dots, S_{|\mathcal{F}|}^H)$, we set $\Omega_{c,i}(\mathbf{S}^H) := \{j \in \mathcal{V}_c \mid i \preceq j \wedge S_j^H < S_i^E \wedge S_j^E > S_i^H\}$ which denotes the subset of flights executed in parallel with flight $i \in \mathcal{V}_c$.

Example 1: Regard flight set $\mathcal{F} = \{1, 2, 3, 4\}$ with $S_1^E = 4, S_2^E = 6, S_3^E = 7$ and $S_4^E = 10$. The time horizon is given by $\mathcal{T} = \{1, \dots, 10\}$. Assume that we assign all 4 flights to circulation 1 and the starting times of the baggage handling is calculated in SP(\mathbf{w}) to $S_1^H = 2, S_2^H = 2, S_3^H = 5, S_4^H = 7$. We have $\Omega_{1,1}(\mathbf{S}^H) = \{1, 2\}$, $\Omega_{1,2}(\mathbf{S}^H) = \{2, 3\}$, $\Omega_{1,3}(\mathbf{S}^H) = \{3\}$ and $\Omega_{1,4}(\mathbf{S}^H) = \{4\}$.

1) *Cuts:* We introduce cuts to consider the storage capacity, which can be violated by the current schedule $\mathbf{S} := (\mathbf{S}^H, \mathbf{S}^D)$ with $\mathbf{S}^D := (S_1^D, \dots, S_{|\mathcal{F}|}^D)$. If this is the case, we may have to left-shift some flights executed during the violation of the storage constraint (Type 1). Furthermore, we have to check whether the schedule still satisfies the constraints given by the assignment of the flights to the circulations. To solve this conflict we have to right-shift some flights (Type 2) (cf. [1]).

- (1.) Storage capacity: Consider subsets $\mathcal{R}_t^1 := \{i \in \mathcal{F} \mid S_i^S \leq t < ES_i\}$ and $\mathcal{R}_t^2 := \{i \in \mathcal{F} \mid ES_i \leq t \leq S_i^D + p_i^D(S_i^H)\}$ for the storage capacity in each time periode $t \in \mathcal{T}$. If inequality

$$\sum_{i \in \mathcal{R}_t^2} G_i(S_i^H, S_i^D, t) \leq \kappa - \sum_{i \in \mathcal{R}_t^1} G_i(S_i^H, S_i^D, t) \quad (12)$$

is not satisfied for some $t \in \mathcal{T}$ we add constraint

$$\begin{aligned} & \sum_{i \in \mathcal{R}_t^1} G_i(S_i^H, S_i^D, t) + \\ & \sum_{i \in \mathcal{R}_t^2} \sum_{\nu=ES_i}^{LS_i} \sum_{z=\nu}^{S_i^E - p_i^D(S_i^H)} G_i(\nu, z, t) \cdot x_{i,\nu,z} \leq \kappa \end{aligned} \quad (13)$$

to problem $\text{SP}(\mathbf{b}, \mathbf{w})$.

- (2.) Connection to the given assignment: For the constraints of parking places and working stations we regard for each $c \in \mathcal{C}$ and $i \in \mathcal{V}_c$ the two inequalities

$$\sum_{j \in \Omega_{c,i}(\mathbf{S}^H)} \varsigma_j \leq P_c \quad (14)$$

$$\sum_{j \in \Omega_{c,i}(\mathbf{S}^H)} w_j \leq W_c. \quad (15)$$

If constraint (14) or (15) is not satisfied for flight i we have to postpone some flights $j \in \Omega_{c,i}(\mathbf{S}^H)$ with $i \neq j$, e.g. we have to right-shift a subset $\Theta \subseteq \mathcal{D}_{c,i} := \{j \in \Omega_{c,i}(\mathbf{S}^H) \mid LS_j \geq S_i^E\}$.

Lemma 2: If (14) or (15) is not satisfied for some $c \in \mathcal{C}$ and $i \in \mathcal{V}_c$, there exist at least one subset $\Theta \subseteq \mathcal{D}_{c,i}$ such that

$$\sum_{j \in \Omega_{c,i}(\mathbf{S}^H) \setminus \Theta} \varsigma_j \leq P_c \quad (16)$$

$$\sum_{j \in \Omega_{c,i}(\mathbf{S}^H) \setminus \Theta} w_j \leq W_c. \quad (17)$$

Proof: This follows immediately if we regard step 1, where we got a feasible assignment of the flights to circulations. \blacksquare

Let $\Delta_{c,i} \subseteq 2^{\mathcal{D}_{c,i}}$ be the set of minimal subsets $\Theta \subseteq \mathcal{D}_{c,i}$ such that constraint (16) and (17) hold. These subsets can be obtained by an enumeration algorithm. If we introduce the additional constraints

$$\sum_{\Theta \in \Delta_{c,i}} y_{\Theta} = 1 \quad (18)$$

$$\begin{aligned} & \sum_{\nu=ES_j}^{LS_j} \sum_{z=\nu}^{S_j^E - p_j^D(S_j^H)} \nu \cdot x_{j,\nu,z} \quad \forall j \in \Omega_{c,i}(\mathbf{S}^H) \\ & \geq \sum_{\Theta \in \Delta_{c,i}: j \in \Theta} y_{\Theta} \cdot S_j^E \end{aligned} \quad (19)$$

to $\text{SP}(\mathbf{b}, \mathbf{w})$ we dissolve the conflict with the parking spaces or working stations.

$\text{SP}(\mathbf{b}, \mathbf{w})$ together with the additional cuts (1.) and (2.) can be stated as a multi-mode RCPSP (MMRCPSP) (cf. [1], [6], [8]): The activities are given by the set of flight \mathcal{F} . The modes are the different starting times of the baggage handling and the starting times of the storage depletion. The mode for each activity $i \in \mathcal{F}$ is set in equation (10). The cuts of the storage capacity in (13) can be regarded as renewable resources. Subset $\Theta \subseteq \mathcal{D}_{c,i}$ and $\Theta \in \Delta_{c,i}$ are delaying alternatives and minimal delaying alternative, respectively (see [1], [6], [9], [8]). Even the described problem represents a special case of the MMRCPSP it remains NP-complete.

Lemma 3: The problem of finding a feasible schedule in terms of storage- and assignment constraints is NP-complete.

Proof: Reduction of the KNAPSACK PROBLEM in polynomial time to $\text{SP}(\cdot, \cdot)$. \blacksquare

D. Assignment Problem 2

After getting a feasible schedule \mathbf{S} in terms of storage-, parking places- and working station capacity, we finally assign the remaining working stations of each circulation $c \in \mathcal{C}$ to the corresponding flights of set \mathcal{V}_c .

To construct the flow network regard graph $G_c = (\mathcal{V}_c, \mathcal{A}_c)$ with node set \mathcal{V}_c and arc set \mathcal{A}_c . For $i, j \in \mathcal{V}_c$ with $i \neq j$ we have $(i, j) \in \mathcal{A}_c$ iff $S_i^E \leq S_j^H$.

Parameter $\mu_{i,t} \in \mathbb{N}$ denotes the *reduction rate* of flight $i \in \mathcal{V}_c$ at time $t \in \mathcal{T}$ if we assign an additional working station to i . With an enumeration algorithm we can calculate reduction rate $\mu_{i,t}$ in $\mathcal{O}(\max_{i \in \mathcal{V}_c} \{S_i^E - ES_i + 1\})$ for all $i \in \mathcal{V}_c$ and $t \in \mathcal{T}$.

With the definitions above we can construct flow network $N_c = (\bar{G}_c, \alpha)$ for each $c \in \mathcal{C}$ in order to optimize the assignment

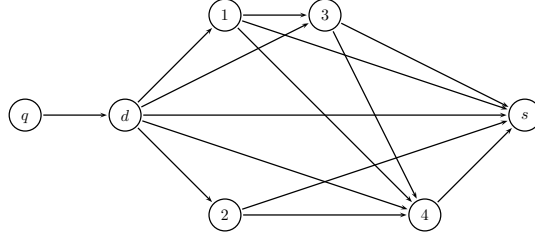


Fig. 3. Flow network of example 1.

of working station to flights. The node set and arc set of network graph $\bar{G}_c = (\bar{\mathcal{N}}_c, \bar{\mathcal{A}}_c)$ is given by $\bar{\mathcal{N}}_c = \mathcal{N}_c \cup \{q, d, s\}$ and $\bar{\mathcal{A}}_c := \mathcal{A}_c \cup \{(d, i) \mid i \in \mathcal{V}_c\} \cup \{(i, s) \mid i \in \mathcal{V}_c\} \cup (q, d)$, respectively. Node q represents the source node, s the sink node and d a dummy node. Figure 3 shows the network graph of example 1 in section II-C. Function $\alpha : \bar{\mathcal{A}}_c \mapsto \mathbb{N}$ gives the upper capacity of the arcs with $\alpha((i, j)) = \hat{\xi}_{j,c}$ and $\alpha((q, d)) = \alpha((i, s)) = W_c$ for all $i, j \in \mathcal{V}_c \cup \{d\}$ with $(i, j) \in \bar{\mathcal{A}}_c$.

Assignment problem 2 (AP2) can now be stated as follows:

$$\begin{aligned} \text{minimize } & \max_{t \in \mathcal{T}} \sum_{i \in \mathcal{V}_c} (T_{i, w_i}(S_i^H, S_i^D, t) - \\ & \left(\left(\sum_{j \in \mathcal{V}_c: (j, i) \in \bar{\mathcal{A}}_c} f_{j, i} \right) - \check{\xi}_{i, c} \right) \cdot \mu_{i, t} \end{aligned} \quad (20)$$

subject to

$$\sum_{j \in \bar{\mathcal{V}}_c \setminus \{q\}: (j, i) \in \bar{\mathcal{A}}_c} f_{j, i} \geq \check{\xi}_{i, c} \quad \forall i \in \mathcal{V}_c \quad (21)$$

$$\sum_{j \in \bar{\mathcal{V}}_c \setminus \{q\}: (j, i) \in \bar{\mathcal{A}}_c} f_{j, i} \leq \hat{\xi}_{i, c} \quad \forall i \in \mathcal{V}_c \quad (22)$$

$$\sum_{j \in \bar{\mathcal{V}}_c: (j, i) \in \bar{\mathcal{A}}_c} f_{j, i} - \sum_{j \in \bar{\mathcal{V}}_c: (i, j) \in \bar{\mathcal{A}}_c} f_{i, j} = 0 \quad \forall i \in \mathcal{V}_c \cup \{d\} \quad (23)$$

$$0 \leq f_{j, i} \leq \hat{\xi}_{i, c} \quad \forall (j, i) \in \mathcal{A}_c \cup \{(d, i) \mid i \in \mathcal{V}_c\} \quad (24)$$

$$0 \leq f_{i, s} \leq \hat{\xi}_{i, c} \quad \forall i \in \mathcal{V}_c \quad (25)$$

$$f_{q, d} = W_c \quad (26)$$

$$0 \leq f_{d, s} \leq W_c. \quad (27)$$

Problem (20) to (27) represents a minimum cost flow problem (MCFP) with a non-linear objective function (cf. [10], [11], [12], [5]). After optimizing problem AP2 for all $c \in \mathcal{C}$ we receive a feasible solution which approximates the minimized maximal global workload under the given assignment of problem AP1 and schedule of problem SP(\mathbf{b}, \mathbf{w}). The corresponding optimal assignment vector of the optimal solution of AP2 will be denoted by \mathbf{w}' .

In the last step of our decomposition heuristic we run problem SP(\mathbf{b}, \mathbf{w}') with the given allocation of working station to flights of AP2. The new solution of SP(\mathbf{b}, \mathbf{w}') is lower or equal than the objective function value of SP(\mathbf{b}, \mathbf{w}).

III. UPCOMING RESEARCH

In this paper we have presented the problem of planning the outbound baggage at international airports. It turns out that the problem can be regarded as a generalisation of the RCPSP, where the resource consumption of the different activities are depending on the arrival process of the baggage. The problem is NP-hard, which leads to high computing times. To reduce the computing times we have decomposed the problem into a generalized assignment problem, a multi-mode RCPSP and a network flow problem with convex cost function. All these problems are also NP-hard to solve, however, they can be handled easier because of their structural properties. To connect the different subproblems with each other we introduced cuts.

In the next step, we will elaborate efficient solution procedures for the different subproblems. Afterwards we will compare our suggested heuristic with the heuristic currently used at Munich Airport and with the MIP formulation of [4]. For the experiments we will use real data of Munich International Airport.

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