Christian-Albrechts-Universität zu Kiel
Wirtschafts- und Sozialwissenschaftliche Fakultät

Planning Shared Passenger and Freight Transport on a Fixed Infrastructure

Lena Hörsting

University of Kiel
Institute of Business
Research Group Service Analytics
Prof. Dr. Catherine Cleophas

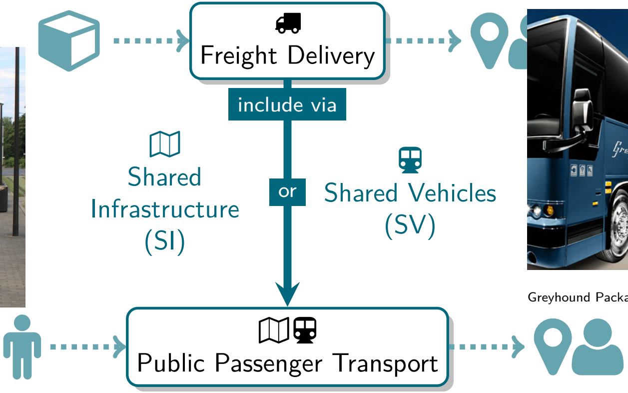
lena.hoersting@bwl.uni-kiel.de

Last-Mile Delivery Workshop, Vallendar

27.06.2022

What is shared passenger and freight transport?

CargoTram in Dresden, Germany (2001-2020)



Greyhound Package Express (USA)

Current pilot projects in Germany

LastMileTram, Frankfurt (Main)

Start: 2018

http://www.relut.de

-Main Logistiktram: Frankfurter Straßenbahnen sollen Pakete transportieren

Frankfurter Allgemeine

Rhein-Main

Frankfurt am Mai

IKEN FRANKFURT REGION UND HESSEN WIRTSCHAFT SPORT KULTUR VERANSTALTUNGEN

EXPERIMENT IN FRANKFURT

Die Straßenbahn soll Pakete transportieren

VON HANS RIEBSAMEN - AKTUALISIERT AM 18.09.2018 - 14:24

Bis in die sechziger Jahre hinein haben Straßenbahnen auch Güter transportiert. Frankfurt experimentiert jetzt wieder mit einer Logistiktram und kann dabei von den bereits gesammelten Erfahrungen profitieren.

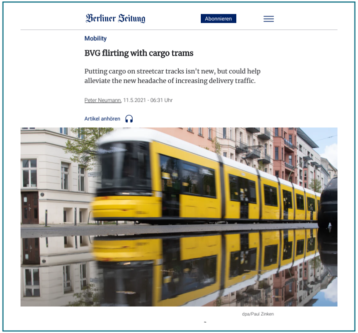
LogIKTram, Karlsruhe

Start: 2021

www.logiktram.de

Cargo-Tram, Berlin

Start: 2021



Berliner Zeitung Abonnieren

Mobility

BVG flirting with cargo trams

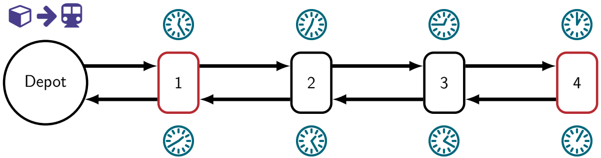
Putting cargo on streetcar tracks isn't new, but could help alleviate the new headache of increasing delivery traffic.

Peter Neumann, 11.5.2021 - 06:31 Uhr

Artikel anhören

dpa/Paul Zinken

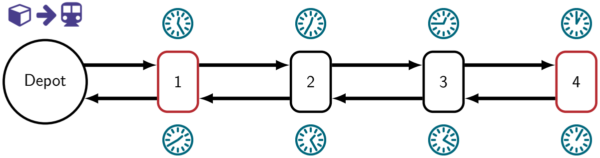
Finding a demand-oriented train schedule



How can we efficiently schedule passengers and freight?

- Circular bi-directional single route
- Given passenger demand as traffic flow (arrival and alighting rate)
- Given freight demand, i.e., freight containers with
  - individual release time
  - soft (and hard) deadline
  - destination stop

Linear program: Decisions



Aperiodic train schedule

- Departure $d_{v,s} \geq 0$ of vehicle v at stop s
- Arrival $a_{v,s} \geq 0$ of vehicle v at stop s
- Dwell time $h_{v,s} \geq 0$ of vehicle v at stop s
- Is vehicle v operating $(o_v = 1)$; or not $(o_v = 0)$?

Freight allocation

- Assign individual freight requests to vehicles
- Is request r loaded to vehicle v at stop s $(y_{r,v,s} = 1)$; or not $(y_{r,v,s} = 0)$?
- Accept $(u_r = 1)$ or reject $(u_r = 0)$ request r?

Linear program: Lexicographical objective

$\mathcal{S}$: stops, $\mathcal{P}$: periods, $\mathcal{R}$: freight requests, P: rejection penalty

$$\operatorname{lex\,min} \left\{ \sum_{s \in \mathcal{S}} \sum_{p \in \mathcal{P}} \frac{w_{s,p}}{|\mathcal{S}| \cdot |\mathcal{P}|}, \sum_{r \in \mathcal{R}} \frac{t_r}{|\mathcal{R}|} + P \cdot (1 - u_r) \right\} \tag{1}$$

1st objective:
Passengers have priority!

- Minimize number of waiting passengers w_{sp} across stops s and periods p

2nd objective:
Reduce freight delay

- Minimize delay t_r of freight request r
- Minimise the number of rejected requests ($u_r = 0$)

Constraints: Headway times, dwell times, service times, capacity, etc.

Linear program: Capacity restrictions

Christian-Albrechts-Universität zu Kiel

Vehicle capacity

©Kay Dreyer, HfG Offenbach, 2019

Dwell time

©J. Schwarze, HfG Offenbach

Station capacity

©Porstner u. Qu, 2019

Image sources: Schocke et al., 2020

Optimisation results with solver

periods	stops	containers	time (sec.)	1st objective sec.	1st objective value	1st objective gap	2nd objective sec.	2nd objective value	2nd objective gap
60	14	0	2091	2091	5.59	0	0	0	0
60	14	10	1604	1554	5.59	0	49	0	0
60	14	20	2522	2502	5.59	0	20	0	0
60	14	30	35067	2658	5.59	0	32400*	0.1	1
60	14	40	4444	2825	5.59	0	1619	0.08	0
60	14	50	2117	2048	5.59	0	69	50000.24	0
180	28	0	32482	32471*	74.09	0.96	1	0	0
180	28	10	36147	32476*	43.7	0.93	3670	0	0
180	28	20	38774	32618*	49.64	0.94	6156	0	0
180	28	30	36065	32618*	45.54	0.93	3456	0	0
180	28	40	36106	32618*	51.96	0.94	3628	0	0
180	28	50	37844	32618*	26.04	0.81	5390	0	0

*runtime-limit exceeded

ALNS

Definition by Pisinger and Ropke, 2010

Algorithm 2 Adaptive large neighborhood search

input: a feasible solution x
$x^b = x$; $\rho^- = (1,\dots,1)$; $\rho^+ = (1,\dots,1)$;
repeat
  select destroy and repair methods $d \in \Omega^-$ and $r \in \Omega^+$ using ρ^- and ρ^+;
  $x^t = r(d(x))$;
  if accept(x^t, x) **then**
    $x = x^t$;
  end if
  if $c(x^t) < c(x^b)$ **then**
    $x^b = x^t$;
  end if
  update ρ^- and ρ^+;
until stop criterion is met
return x^b

Work of Yin et al., 2021

- ALNS for demand-oriented timetabling problem
- Each neighbor represents a timetable

This work's extension

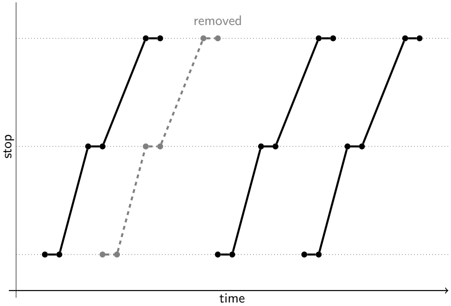
- Addition of cargo favouring repair operators
- Inclusion of cargo allocation problem (solved with Gurobi)

Destroy Operators (Yin et al., 2021)

CAU Christian-Albrechts-Universität zu Kiel

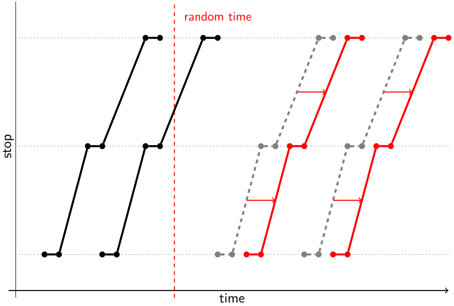
Random deletion

- Randomly select a vehicle
- Remove selected vehicle



Random shift

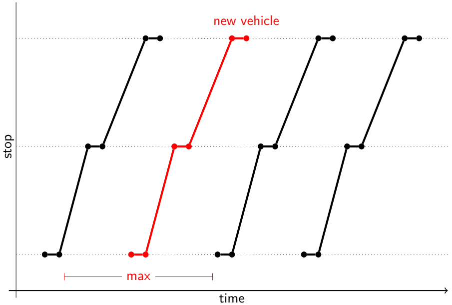
- Randomly select time, direction of shift and shift interval
- Shift all vehicles departure before/after the selected time



Repair Operators (Yin et al., 2021)

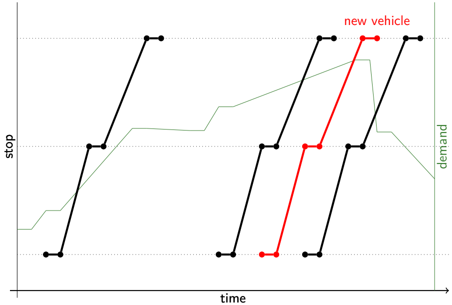
Greedy temporal insertion

- Detect the largest (feasible) time slot in-between two vehicles.
- Insert vehicle in the centre of the time slot.
- Repeat.



Greedy passenger demand insertion

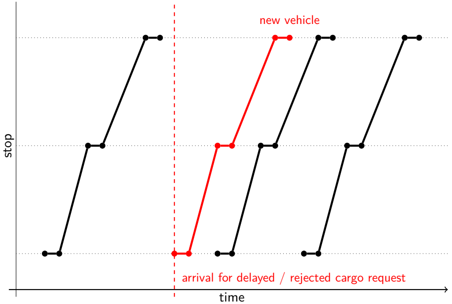
- Detect (feasible) time slot with highest passenger congestion.
- Insert vehicle in the time slot.
- Repeat.



Repair Operators (Extension)

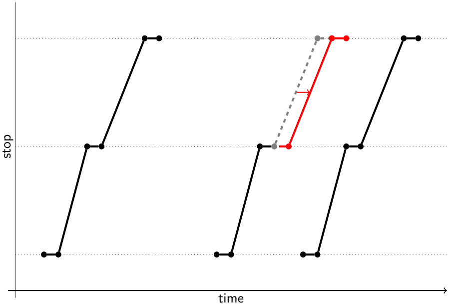
Greedy freight demand insertion

- Detect rejected cargo request OR cargo request with highest delay
- Insert vehicle in the next feasible time slot after cargo request release.
- Repeat.



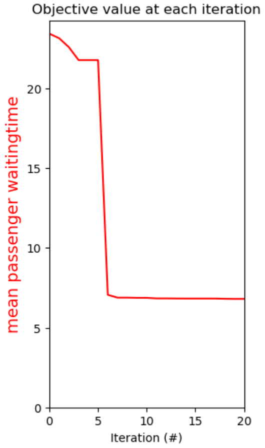
Increase service time buffer

- Detect the vehicle and stop with minimal slack between service and dwell time.
- Increase the dwell time by one time unit.

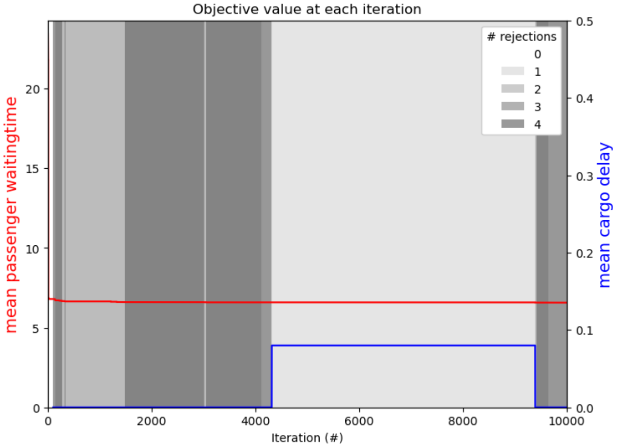


Development of the lexicographical objective function

20 iterations



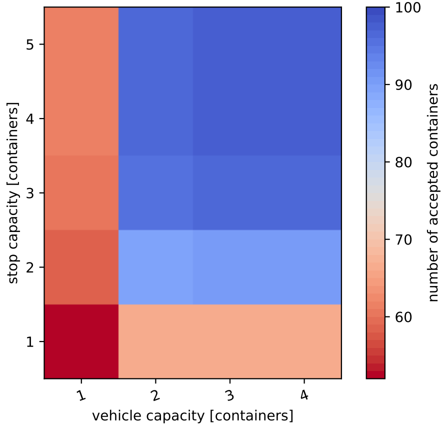
10000 iterations



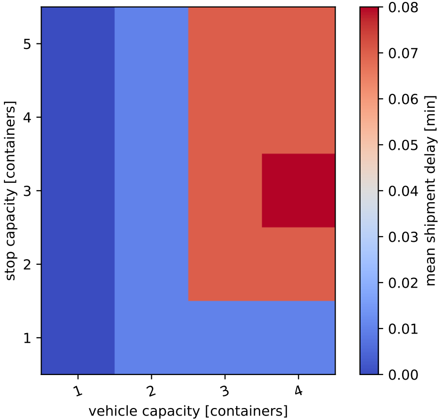
First results

Cargo service evaluation for varying capacities

Accepted containers



Mean container delay



- Model supports, e.g., estimation of required cargo capacity for stops and vehicles.

Conclusion

Christian-Albrechts-Universität zu Kiel

Summary

- ☑ Bi-objective train schedule and cargo allocation: Passengers first, cargo second
- ☑ Extension of Adaptive Large Neighbourhood Search by Yin et al., 2021
- ☑ Integration of cargo allocation problem

Next steps

- ☐ Store and consider intermediate solutions
- ☐ Different representative instances to consider stochasticity (currently expected values)
- ☐ *Tram für Kiel:* Real data provided by city Kiel

Thank you for your attention! Questions?

Christian-Albrechts-Universität zu Kiel

Working paper available at SSRN: https://ssrn.com/abstract=3886691

Contact Information: Lena Hörsting, lena.hoersting@bwl.uni-kiel.de, www.csa.bwl.uni-kiel.de

References

Behiri, W., Belmokhtar-Berraf, S., & Chu, C. (2018). Urban freight transport using passenger rail network: Scientific issues and quantitative analysis. *Transportation Research Part E: Logistics and Transportation Review*, *115*, 227–245.

Ghilas, V., Demir, E., & Van Woensel, T. (2016). An adaptive large neighborhood search heuristic for the pickup and delivery problem with time windows and scheduled lines. *Computers & Operations Research*, *72*, 12–30.

Li, Z., Shalaby, A., Roorda, M. J., & Mao, B. (2021). Urban rail service design for collaborative passenger and freight transport. *Transportation Research Part E: Logistics and Transportation Review*, *147*, 102205.

Masson, R., Trentini, A., Lehuédé, F., Malhéné, N., Péton, O., & Tlahig, H. (2017). Optimization of a city logistics transportation system with mixed passengers and goods. *EURO Journal on Transportation and Logistics*, *6*(1), 81–109.

Motraghi, A., & Marinov, M. V. (2012). Analysis of urban freight by rail using event based simulation. *Simulation Modelling Practice and Theory*, *25*, 73–89.

Ozturk, O., & Patrick, J. (2018). An optimization model for freight transport using urban rail transit. *European Journal of Operational Research*, *267*(3), 1110–1121.

Pisinger, D., & Ropke, S. (2010). Large neighborhood search. *Handbook of metaheuristics* (pp. 399–419). Springer.

Schocke, K.-O., Schäfer, P. K., Höhl, S., & Gilbert, A. (2020). *LastMileTram - Empirische Forschung zum Einsatz einer Güterstraßenbahn am Beispiel Frankfurt am Main. Abschlussbericht* (tech. rep.). Frankfurt University of Applied Science.

Yin, J., D'Ariano, A., Wang, Y., Yang, L., & Tang, T. (2021). Timetable coordination in a rail transit network with time-dependent passenger demand. *European Journal of Operational Research*.