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Multimodal processes optimization subject to fuzzy operation time constraints: declarative modeling approach

Key words: Automated guided vehicles (AGVs), Scheduling, Multimodal process, Fuzzy constraints, Optimization

Contact: Robert Wójcik
E-mail: robert.wojcik@pwr.wroc.pl
ORCID: http://orcid.org/0000-0003-3860-7011

Introduction

- Much research on the fleet assignment and maintenance planning problems assume that routing and allocation as well as batching and scheduling decisions are made **independently** and are oriented at finding a minimal production takt while assuming **deadlock-free processes flow**.
- Our main contribution is to propose a declarative framework aimed at refinement and prototyping of the cyclic steady states for concurrently executed material handling systems composed of AGVs competing for the access to the common shared resources.

Fig. 1 Exemplary multimodal transportation network (MTN) (a) and its systems of concurrently flowing cyclic process (SCCP) representation (b)

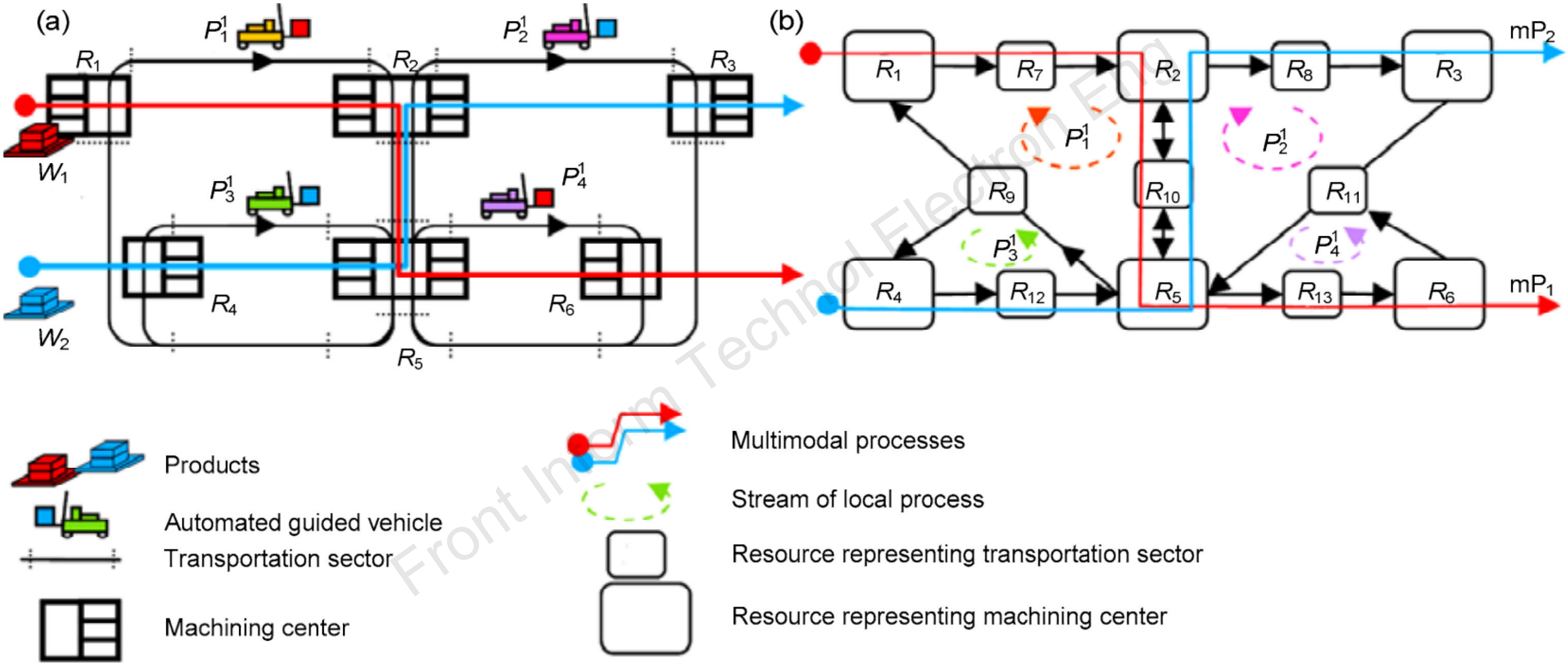


Table 1 Awaiting working times of operations for multimodal processes mP_1 and mP_2

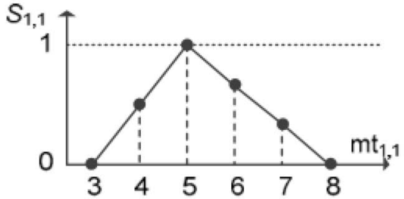
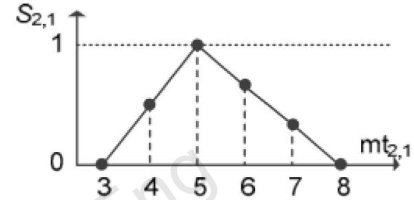
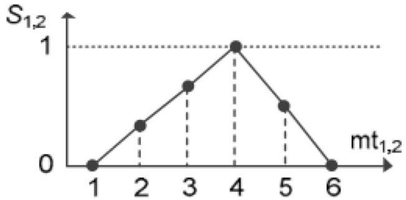
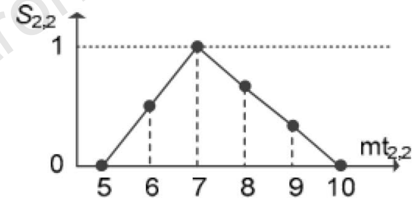
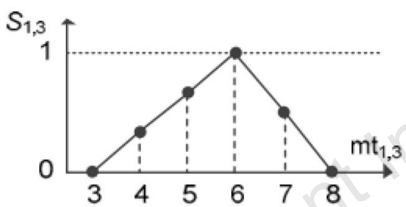
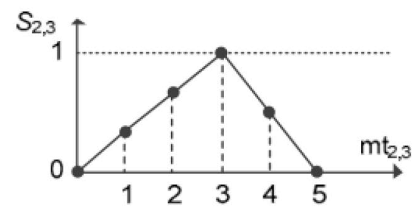
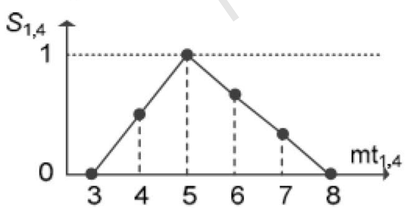
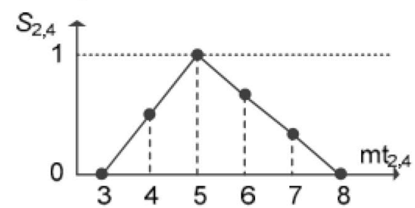
Awaiting working times for mP_1	Awaiting working times for mP_2
	
Working time $mt_{1,1}$ of operation assigned to R_1 is 'about 5'	Working time $mt_{2,1}$ of operation assigned to R_4 is 'about 5'
	
$mt_{1,2}$ is 'about 4' (on R_2)	$mt_{2,2}$ is 'about 7' (on R_5)
	
$mt_{1,3}$ is 'about 6' (on R_5)	$mt_{2,3}$ is 'about 3' (on R_2)
	
$mt_{1,4}$ is 'about 5' (on R_6)	$mt_{2,4}$ is 'about 5' (on R_3)

Table 2 Expected profitability measured by production takt of processes mP_1 and mP_2

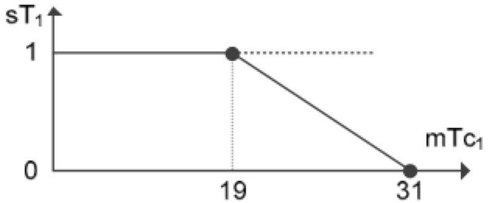
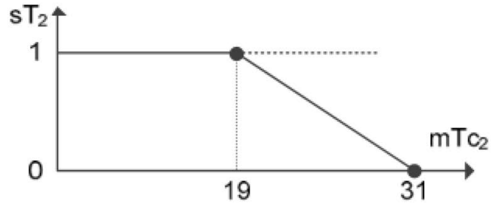
Production profitability measured along mP_1	Production profitability measured along mP_2
 Production takt mTc_1 less than 19	 Production takt mTc_2 less than 19

Fig. 3 The cyclic schedule for the automated guided vehicle system from Fig. 1 which guarantees *S*=1 and *E*=0.416

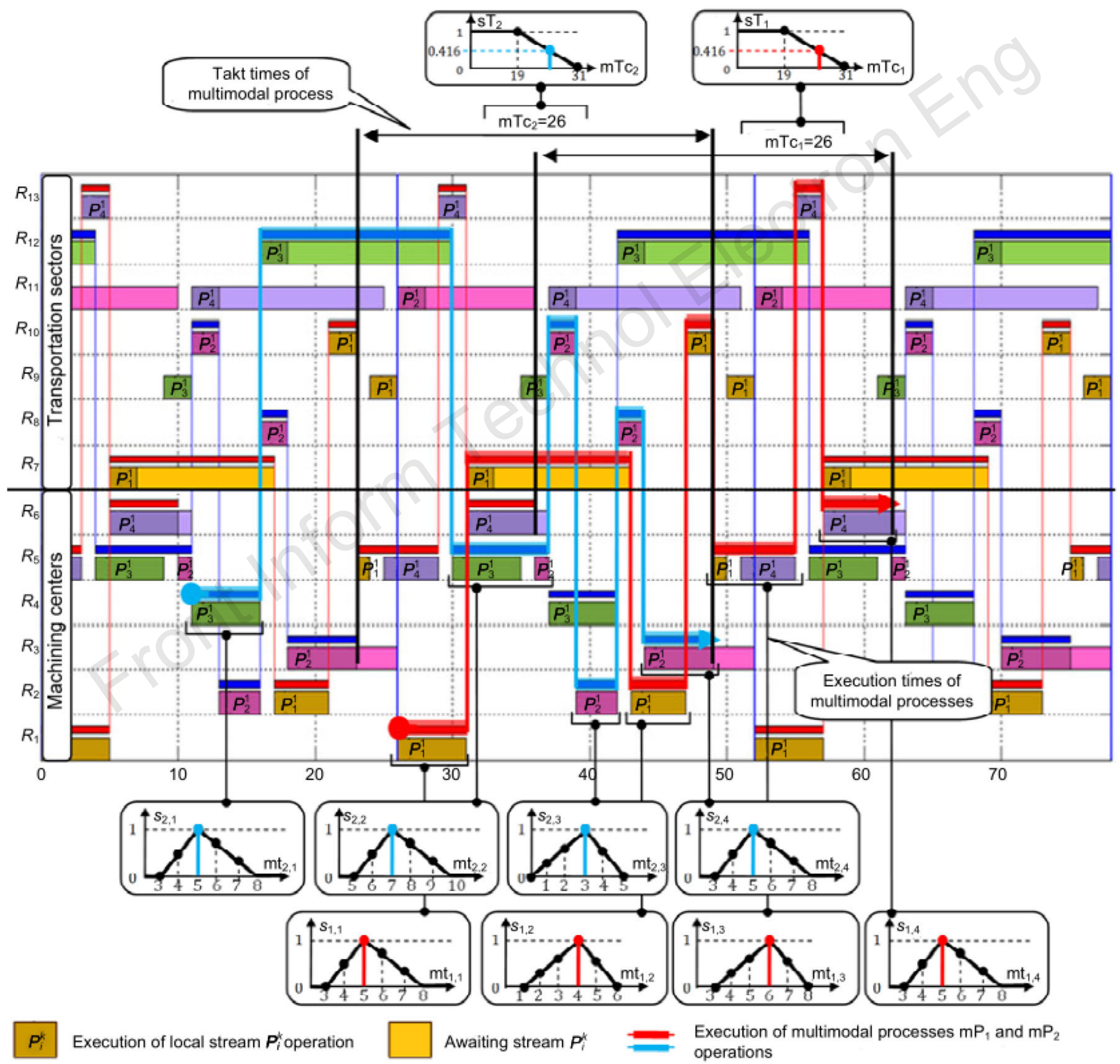


Fig. 4 Space of admissible schedules $\mathbb{L}$ including *L* solutions for the system from Fig. 1 parameterized by *S* and *E* (a), and 'top-down view'—elevation of $\mathbb{L}$ onto the *S*-*E* plane (b)

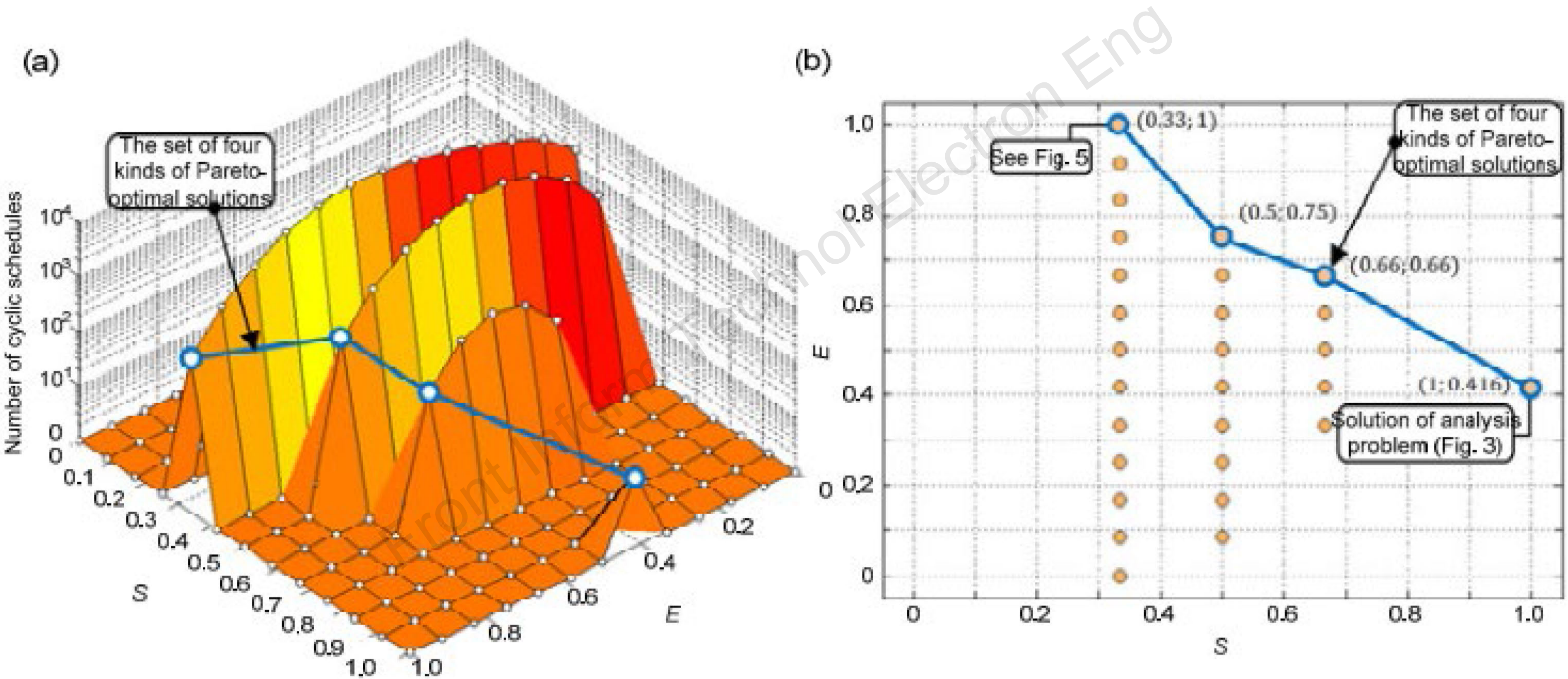


Fig. 5 The cyclic schedule for the automated guided vehicle system from Fig. 1 which guarantees *S*=0.33 and *E*=1

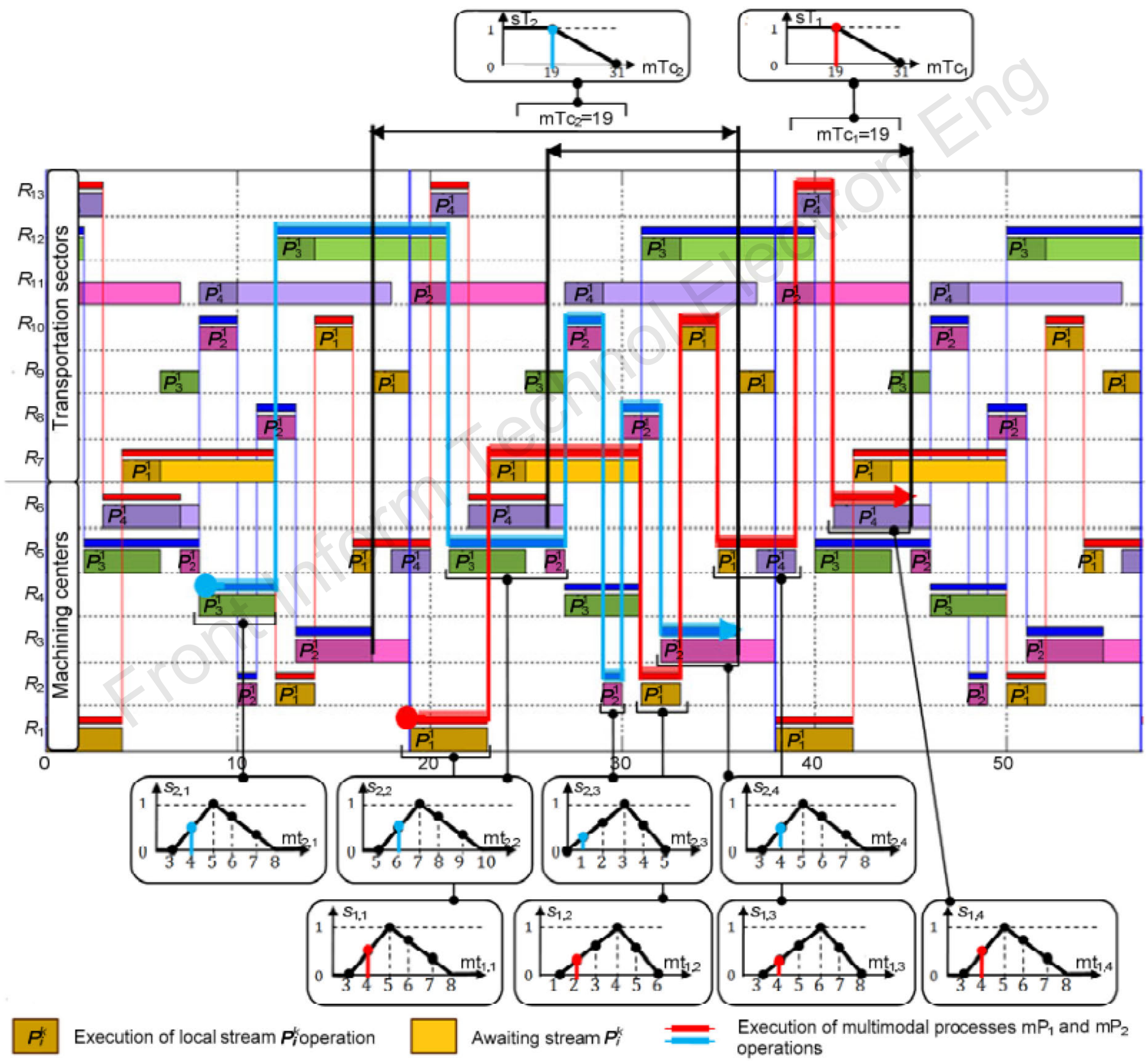


Table 3 Calculation times required for solutions of analyzing and synthesizing different scale problems

Size of SCCP (number of local processes)	Computation time (s)*	
	SCCP analysis (variables: X_{SC})	SCCP synthesis (variables: $T(t_{i,j}^k \in \{1,2,\ldots,6\})$ and X_{SC})
3	<1	5
4**	<1	30
5	<1	111
10	3	4213
15	5	>7200***
20	7	>7200***
30	10	>7200***

* Computational environment: OzMozart with Intel Core 2 Duo 3 GHz CPU and 4 GB RAM; ** considered example (Figs. 1–5); *** after 7200 s computations have been stopped

Conclusions

- The considered declarative modeling driven approach offers a unified method for performance evaluation of local and multimodal processes supported by them.
- The provided sufficient conditions make it possible to design an AGV transportation network in such a way as to obtain the final AGVs fleet schedule guaranteeing the required quantitative and qualitative features.