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Adaptive production scheduling and control for one-of-a-kind production (OKP)

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Agenda

- Introduction to production scheduling
- Characteristics of one-of-a-kind production (OKP)
- Difficulties in production scheduling and control for OKP
- Gienow Windows and Doors Co. Ltd.
- Case studies
- Conclusion

Production Scheduling

- Production scheduling:
  - to allocate the jobs/orders to competing resources based on objectives
  - makespan, past due, work-in-process inventory (WIP)
- For a *n*-job *m*-machine problem: (*n!*)
  - For traditional flow shop (TFS) problems:

    10 jobs –> (*10!*) = 3,628,800
- Non-deterministic polynomial (NP) problems

Production Scheduling

- Algorithms (Johnson's algorithm, BB, LP, etc.)
  - Optimality: optimal solutions
  - Computation speed: slow
- Constructive heuristics (NEH, CDS, PDRs., etc.)
  - Optimality: not optimal solutions
  - Computation speed: fast
- Meta-heuristics (Adaptive learning, GA, NNs, etc.)
  - Optimality: more close to optimal solutions
  - Computation speed: depends on the size of problem

Production Scheduling

- Johnson's algorithm – 1954
  - Computational complexity: $O(nlogn)$
- CDS – 1970
  - Computational complexity: $O(m^2n+mnlogn)$
- NEH – 1983
  - Computational complexity: $O(n^3m)$
  - Taillard (1990): $O(n^2m)$
- NEH is the best constructive heuristic

One-of-a-Kind Production

- To produce highly customized products at a production efficiency as high as mass production.

- "Once" successful development of the product, i.e. no prototype in a product development life cycle.
  - Product design, testing, and production are carried out concurrently.

One-of-a-Kind Production

- The product requirements may be changed at any time within the product development cycle.
- Virtual OKP: A virtual manufacturing company consists of a number of units geographically dispersed but managed as one total unit although the sub-units may be under separate management.

In a word, there are a lot of changes in OKP.

Difficulties in OKP

- For scheduling:
  - No comprehensive solutions, just respectively on makespan, WIP, etc.
- For control:
  - Computation speed for big problems is slow.

Difficulties in OKP

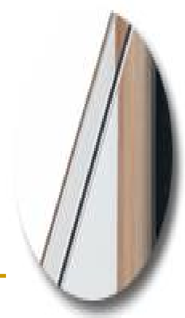
- For OKP:
  - Continuous changes from customers.
  - Hybrid flow shop (HFS) problems: *n* – job, *m* – work center problems, and there are more than one machines or operators in one work center.
  - Simulation model.

Gienow

1 7/8" THICK METAL CLAD SASH

The western pine frame clad with thick extruded aluminum, provides a low maintenance exterior and adds the warmth and beauty of wood to the interior.

WARM EDGE SEALED UNIT



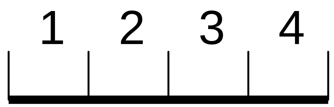
Warm edge insulated sealed unit is standard. Optional SOL-R® to provide maximum energy efficiency in all climates.

DESIGNER COLORS

The maintenace-free aluminum clad exterior is available in a wide array of colors to compliment any decor.

Gienow

- An OKP company
- 14 main production lines
- 3 days scheduling policy



- Difficulty on dealing with emergencies

Gienow

- For simulation
  - A temporized hierarchical object-oriented colored Petri net with changeable structures (THOPN-CS)
  - Four levels:

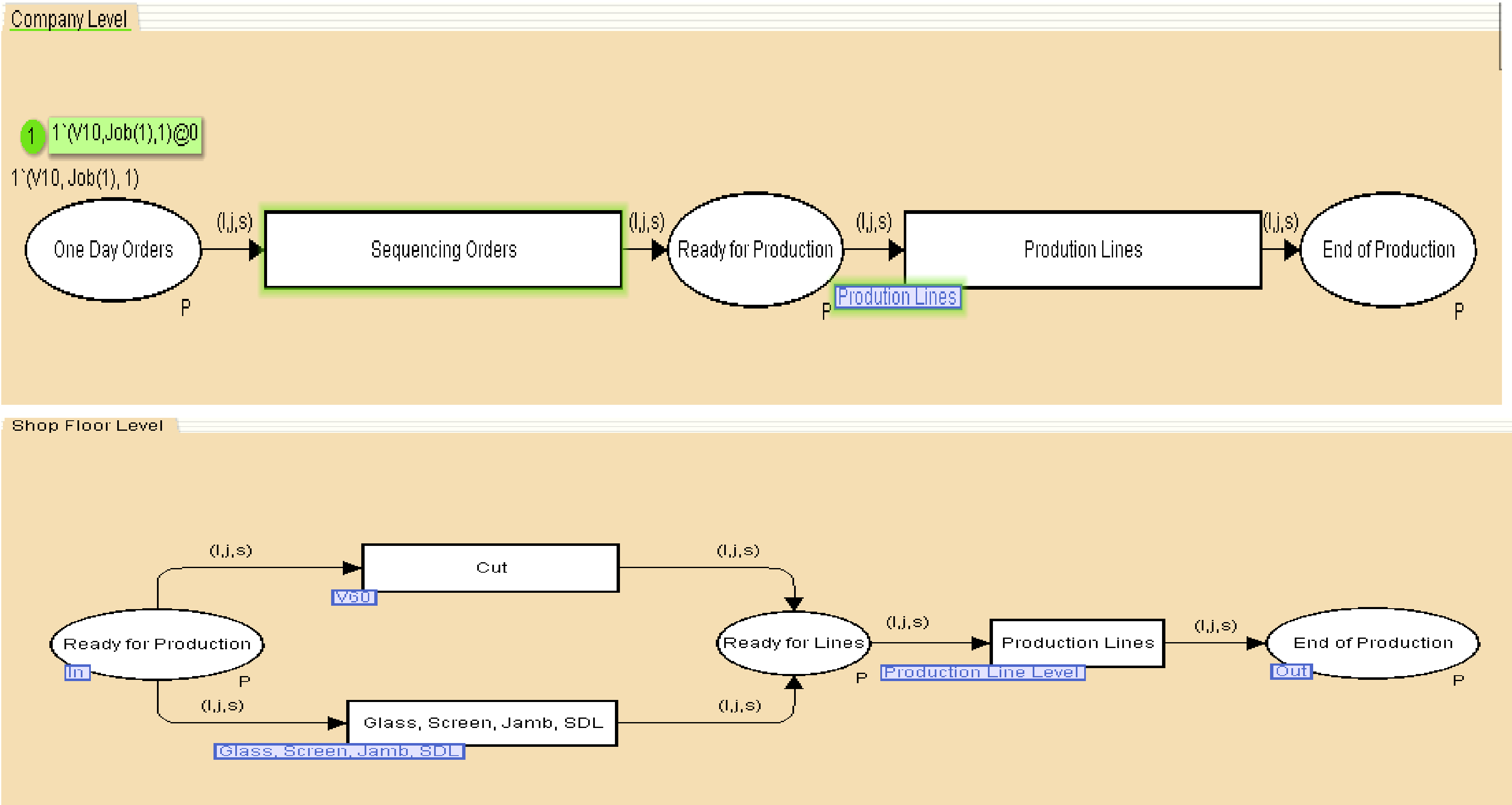
    (1) company level

    (2) shop floor level

    (3) production line level

    (4) facility level

Four levels of THOPN-CS



Four levels of THOPN-CS

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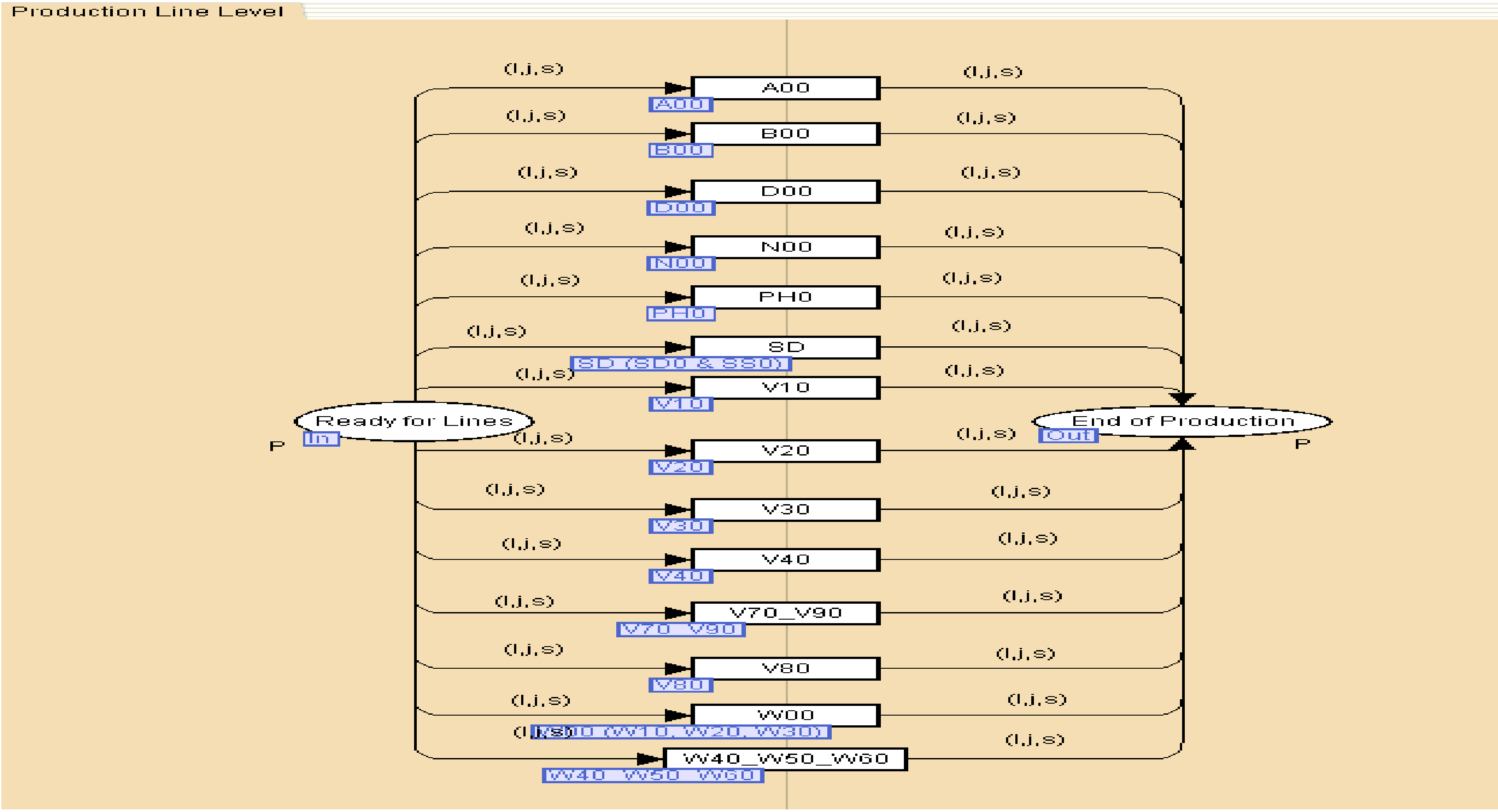
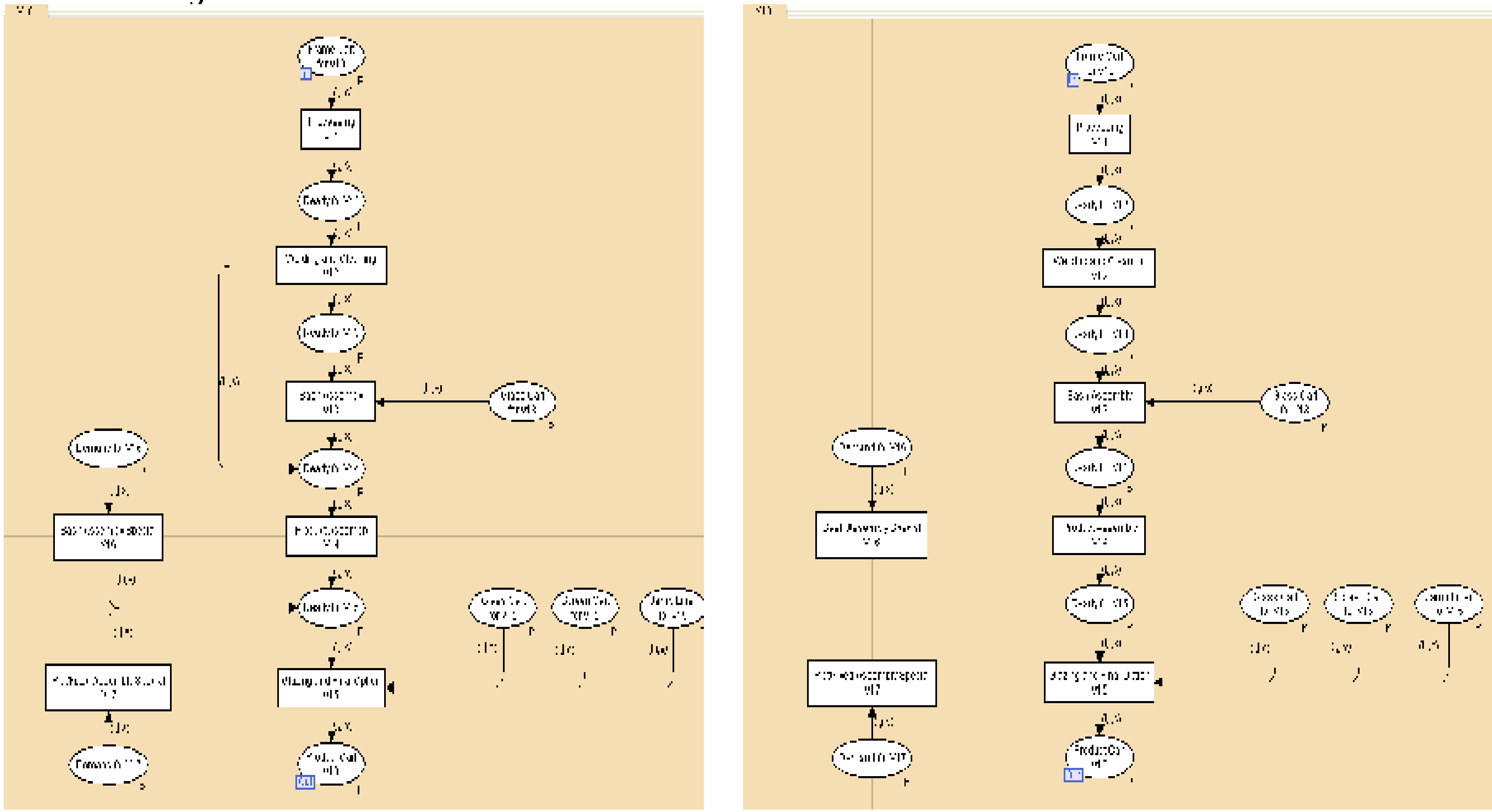
Production Line Level



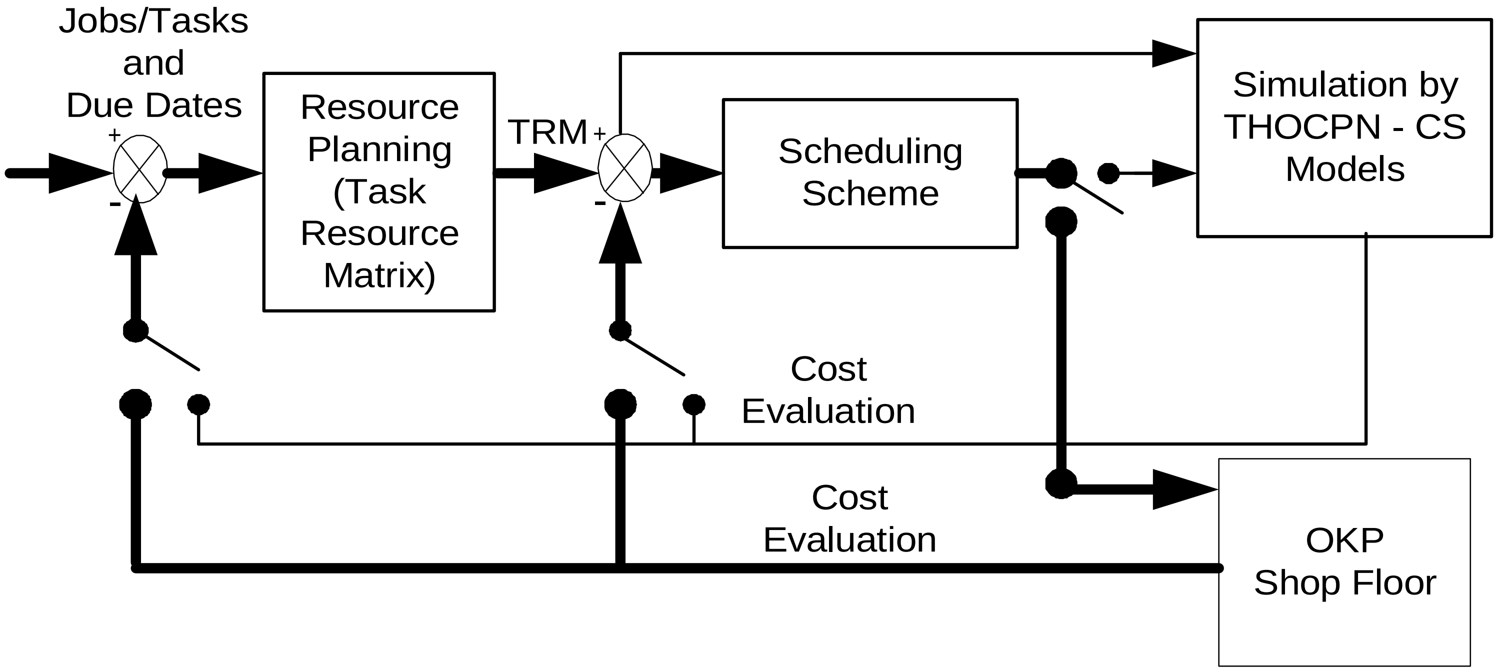
Four levels of THOPN-CS

Facility Level



Adaptive Control Scheme

- For control
  - Adaptive control on THOCPN-CS



Case Studies

- For scheduling
  - APT-LVR: min (makespan)
  - Five sub-heuristics:

    APT-1, APT-2, APT-3, APT-4, APT-5
  - Computational complexity: $O(m^2n+mnlogn)$
  - Two case studies:
    - A case study on benchmarks
    - An industrial case study

A case study on benchmarks

TABLE 1 Average Deviations from Benchmarks

FOR TAILLARD'S PROBLEMS									
Problem	Instance	NEH(%)	CDS(%)	APT-LVR(%)	APT-1(%)	APT-2(%)	APT-3(%)	APT-4(%)	APT-5(%)
20*5	10	3.27	9.05	5.92	9.60	9.65	9.17	7.82	8.06%
20*10	10	4.94	13.48	9.51	13.10	12.25	11.01	10.60	11.09
20*20	10	3.67	11.07	8.72	9.90	11.03	9.82	9.67	9.56
50*5	10	0.75	7.15	3.43	7.19	7.41	5.85	4.55	3.95
50*10	10	5.52	14.46	10.66	14.35	14.59	12.60	11.85	11.29
50*20	10	7.98	18.13	14.02	17.83	17.94	15.23	14.78	14.83
100*5	10	0.38	5.25	2.29	4.56	4.94	2.98	3.00	3.54
100*10	10	2.40	9.51	6.74	10.02	9.54	7.70	7.43	7.14
100*20	10	6.19	16.45	12.43	16.40	16.45	14.50	13.26	12.68
200*10	10	10.20	7.55	5.03	7.56	7.38	6.04	5.49	5.30
200*20	10	4.63	13.75	10.41	13.30	13.33	11.31	10.83	10.74
500*20	10	2.07	9.56	6.67	9.56	9.57	7.38	7.13	6.77
Total Average		4.33	11.28	7.99	11.12	11.17	9.47	8.87	8.75
FOR CARLIER'S PROBLEMS									
Average	8	1.39	6.27	2.97	5.00	4.21	4.84	4.12	3.67
FOR HELLER'S PROBLEMS									
Average	2	1.23	12.11	8.25	12.32	11.65	8.34	8.54	8.25
FOR REEVES' PROBLEMS									
Average	21	4.88	13.37	10.02	13.01	12.93	10.43	10.59	10.38

An industrial case study

1396 jobs on V10 line with 5 work centers, APT-LVR: 782 ms, NEH: > 5 hr

TABLE 2 AN INDUSTRIAL CASE STUDY

	Gienow	APT-LVR	Improvement		Gienow	APT-LVR	Improvement
1	1,795	1,711	84	16	1,489	1,478	11
2	1,458	1,441	17	17	1,477	1,466	11
3	1,698	1,689	9	18	1,743	1,701	42
4	2,292	2,261	31	19	1,751	1,734	17
5	1,570	1,556	14	20	1,434	1,431	3
6	1,798	1,753	45	21	1,587	1,570	17
7	1,420	1,412	8	22	1,587	1,393	194
8	1,573	1,556	17	23	1,196	1,165	31
9	1,828	1,798	30	24	1,094	1,083	11
10	1,676	1,676	0	25	1,362	1,362	0
11	1,568	1,557	11	26	1,281	1,281	0
12	1,691	1,680	11	27	923	923	0
13	1,465	1,465	0	28	857	851	6
14	1,364	1,353	11	Total	42,300	41,669	631
15	1,323	1,323	0	Percent			1.49%

Conclusion

- APT-LVR has the same computation complexity as CDS, but can get more optimal solutions.
- APT-LVR is efficient for production scheduling and control for OKP

THANKS!

- Questions?
- Suggestions?
- Concerns?