If you want to refer to this presentation, please refer to:

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The data used in this presentation will be made available on our website:

https://www.projectmanagement.ugent.be/research/data

FACULTY OF ECONOMICS AND BUSINESS ADMINISTRATION

A NEW SOLUTION PROCEDURE FOR MULTI-SKILLED RESOURCES IN RESOURCE-CONSTRAINED PROJECT SCHEDULING

Jakob Snauwaert and Mario Vanhoucke

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INTRODUCTION

- What?
  - Multi-skilled resource-constrained project scheduling problem (MSRCPSP)
  - Solving MSRCPSP for different workforces
- How?
  - Problem-specific algorithm
- Goal?
  - Identify efficient Workforce - Project combinations
    - Workforce size and characteristics
    - Project network and requirements

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OUTLINE

- MSRCPSP with breadth and depth
- Solution Approach
- Managerial insights
- Future research perspectives

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MSRCPSP

- Multi-skilled resource-constrained project scheduling problem (Bellenguez & Néron, 2004)
- Schedule activities and assign multi-skilled resources
- Activity characteristics:
  - Standard duration
  - Activities require skills
- Resources can execute activities only if they master the required skills
- Resources can only fulfil one skill per activity
- Skill availability is the amount of resources that master a skill
- Goal:
  - Find a feasible project schedule and resource assignment
  - Minimise the project duration

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MSRCPSP WITH BREADTH AND DEPTH

- Multi-skilled resource-constrained project scheduling problem (Bellenguez & Néron, 2004)
- Resource characteristics:

1. **Breadth**: amount of skills a resource masters (categorical skills)
   - Flexibility of a resource
   - Breadth = 1: single-skilled resource
   - Breadth > 1: multi-skilled resource
2. **Depth**: the efficiency level at which a skill will be performed (hierarchical skills)
   - Experience of a resource for each skill
   - Depth = 1: default efficiency level
   - Depth > 1: more efficient
   - Depth < 1: less efficient

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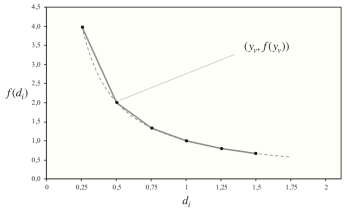
MSRCPSP WITH BREADTH AND DEPTH

- Variable activity duration: the duration is based on the depth of the resources assigned to the activity
- Activity processing time estimation method
  - We propose a reciprocal relation between the adjusted processing time of an activity and the average depth of the assigned resources
  - $p_i^a = p_i \cdot \frac{1}{\min_j \overline{d_{ij}}}$ with $\overline{d_{ij}} = \frac{\sum_k d_{jk} \cdot x_{ijk}}{r_{ij}}$
  - A resource with a high depth can compensate for a resource with a low depth
  - Resources that perform a different skill have no impact on each other
  - Solved using linear approximation



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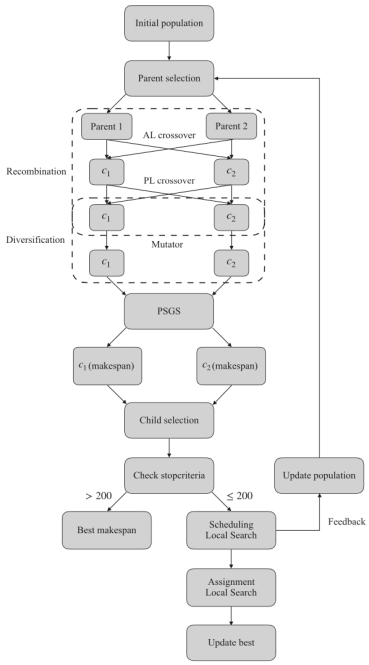
BASIC APPROACH

- Genetic algorithm
  1. Initial population
  2. Parent selection
  3. Crossovers
  4. Mutation
  5. Parallel scheduling generation scheme
  6. Local searches



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REPRESENTATION

- A vector of 2n numbers that represent the project schedule and resource assignment (n = number of activities)
- Activity List (AL): precedence feasible list that displays the priority of the activities (Hartmann (1998))
- Priority Rule List (PL): list in which each activity is appointed a priority rule that determines the resource assignment

Solutions

	AL				PL			
S1:	1	2	3	4	1	2	2	1
S2:	1	2	3	4	2	2	2	1

Priority Rules

RPRL[1] = [R1,R2,R3]

RPRL[2] = [R2,R3,R1]

Workforce

Resources \ Skills	1	2	3
1	1.2		
2		1	0.8
3	1	0.8	

Requirements (activity 1)

Activity \ Skills	1	2	3
1	1	1	0

Assignment (activity 1)

Resources \ S1	1	2	3
1	x		
2		x	
3			

Resources \ S2	1	2	3
1			
2		x	
3	x		

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BASIC RESOURCE PRIORITY RULES

– 9 problem-specific priority rules

Breadth	Depth	Resource criticality
Lowest breadth first	Highest average depth first	Lowest basic resource criticality first
Highest breadth first	Lowest total negative depth first	Lowest advanced resource criticality first
Lowest grouped breadth first	Lowest average depth first	Highest advanced resource criticality first

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GENERATED RESOURCE LISTS

– A vector of n+r numbers that represent the project schedule and resource assignment (n = number of activities and r = number of resources)
– Activity List (AL): precedence feasible list that displays the priority of the activities Hartmann (1998)
– Resource List (RL): list that determines the priority of the resources in the resource assignment
– Example resource list: **S1:**

	AL				RL		
	1	2	3	4	1	2	3

– Each instance was solved using the GA with resource lists
– The resource lists that yielded the best found objective values were then added to the set of priority rules for the PL

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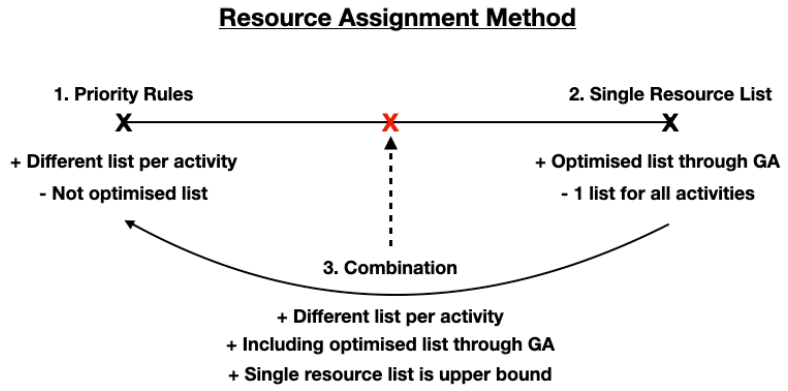
EXTENDED APPROACH + RESULTS



- Results (in % improvement)

	RL	PL (Basic PR set)	PL(with resource lists)
Average makespan difference (in %)	Benchmark	-3.8%	-5.7%

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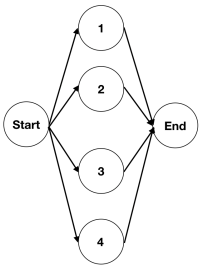
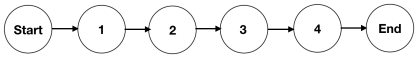
MANAGERIAL INSIGHTS

- Parallel projects: Focus on the multi-skilledness



- Serial projects: Focus on efficient workers



- Workforce comparison for a single project
  - Cost is calculated based on the workforce characteristics and the makespan of the project

Workforce	Number of resources	Average breadth	Project Duration (days)	Cost (€)
1	High	High	46.5	120,960
2	High	Low	58.4	108,097
3	Med	Med	75.5	92,961
4	Low	High	94.2	103,930
5	Low	Low	107.6	108,072

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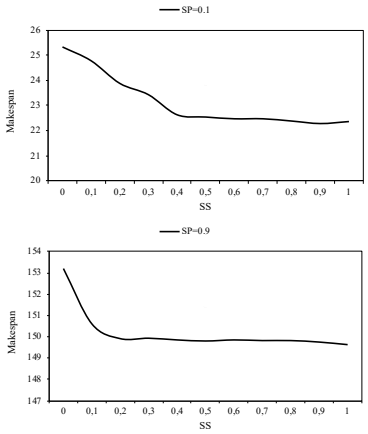
MANAGERIAL INSIGHTS

- **How many mastered skills in a workforce?**
  - The number of mastered skills should be less than or equal to 40% of the total skill requirements in the project
  - A higher amount of mastered skills in the workforce does not lead to a lower makespan in most cases
- For parallel projects (SP=0.1):
  - The amount of skills should be lower than 40% for parallel projects
- For serial projects (SP=0.9):
  - A number of skills higher than 20% of the total skill requirements does not lower the makespan



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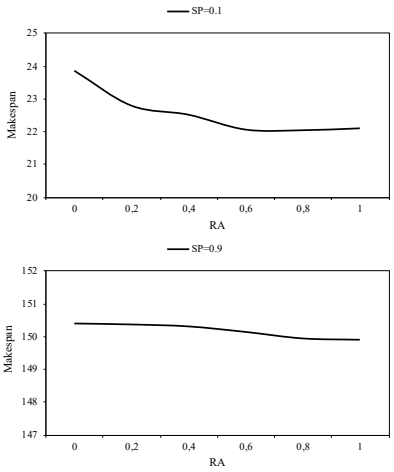
MANAGERIAL INSIGHTS

- **How big should the workforce be in number of resources?**
  - The number of resources in the workforce has a smaller impact on the makespan than the number of mastered skills
- For parallel projects (SP=0.1):
  - The makespan is higher for lower resources numbers due to the skill constraints
  - If the number of resources is on average higher than 60% of the number of mastered skills there is no improvement in the makespan
- For serial projects (SP=0.9):
  - The number of resources has very little impact on the makespan for more serial projects
  - It does not matter if the workforce consists of single-skilled workers or multi-skilled workers



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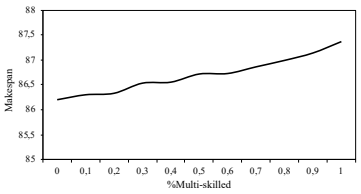
MANAGERIAL INSIGHTS

- **How many resources need to be multi-skilled in the workforce?**
  - The higher the percentage of multi-skilled workers in the workforce the higher the makespan
  - A workforce with only multi-skilled workers needs to increase their number of skills with on average 18% of the total requirement to yield equivalent objective values than their single-skilled counterpart



  - 18% extra skills are required to deal with the fact the multi-skilled resources can only perform one of their mastered skills at the same time.
- For parallel projects (SP=0.1):
  - This value can be up to 50%
- For serial projects (SP=0.9):
  - The required number of extra skills converges to 0%
- These results can help managers decide whether the total cost of training multi-skilled workers will be lower than the salary cost of the additional single-skilled workers

FUTURE RESEARCH PERSPECTIVES

- Further analyse cost objective
  - Hire an extra worker or train a new skill for an existing worker?
- Research other kinds of impact of depth:
  - Cost
  - Task restriction
  - Quality
  - Assignment effectivity
  - Commodity usage

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