GHENT UNIVERSITY

FACULTY OF ECONOMICS AND BUSINESS ADMINISTRATION

BUSINESS INFORMATICS AND OPERATIONS MANAGEMENT

AN ANALYSIS OF CRITICAL ALTERNATIVES IN THE RCPSP-AS

dr. Tom Servranckx
Prof. Mario Vanhoucke

If you want to refer to this presentation, please refer to Servranckx, T., Vanhoucke, M., and Vanhouwaert, G., 2020, “Analysing the impact of alternative network structures on resource-constrained schedules: Artificial and empirical experiments”, Computers and Industrial Engineering, 148, 106706. Download the project cards of the case studies from the website www.projectmanagement.ugent.be.

GHENT UNIVERSITY

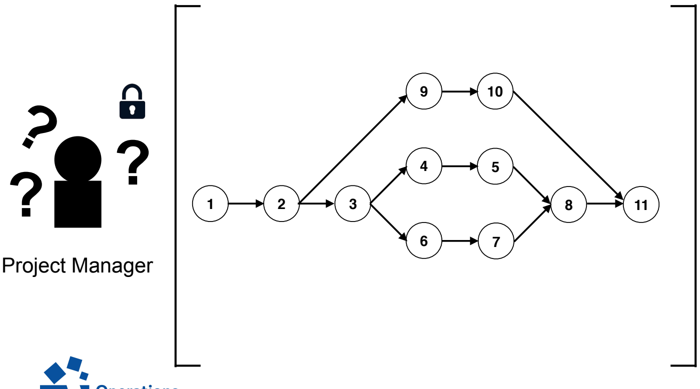
Operations Research & Scheduling

17th Int'l Conference on Project Management and Scheduling, April, 21-23 (2020/2021), Toulouse

INTRODUCTION

Resource-constrained project scheduling problem with alternative subgraphs (RCPSP-AS):

- Extension of the traditional RCPSP
  - Highly <u>complex</u> and <u>uncertain</u> project environment
  - Fixed project structure is impossible and impractical



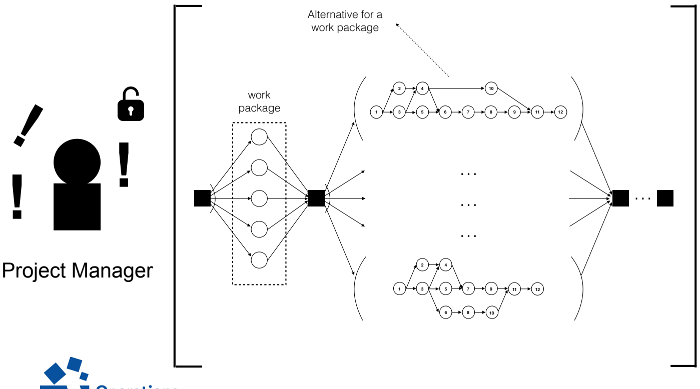
GHENT UNIVERSITY

Operations Research & Scheduling

INTRODUCTION

Resource-constrained project scheduling problem with alternative subgraphs (RCPSP-AS):

- Extension of the traditional RCPSP
  - Highly <u>complex</u> and <u>uncertain</u> project environment
  - Fixed project structure is impossible and impractical
- **Selection** and **scheduling** subproblem
  - The objective is to select for each work package exactly one alternative execution mode such that the makespan of the resulting project is minimised



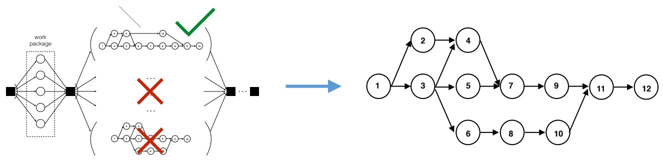
GHENT UNIVERSITY

Operations Research & Scheduling

INTRODUCTION

Solution approaches

- Meta-heuristic solution approaches: solve both subproblems in a sequential/integrated way
  - Find best set of alternatives in the project structure
  - Rapidly generate high-quality schedule
  - Single best solution, but what about the non-selected alternatives?



Optimal project structure

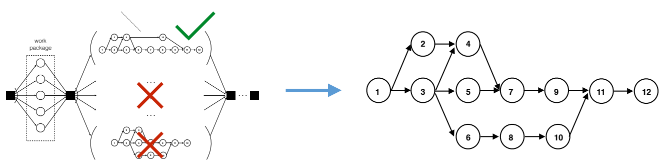
GHENT UNIVERSITY

Operations Research & Scheduling

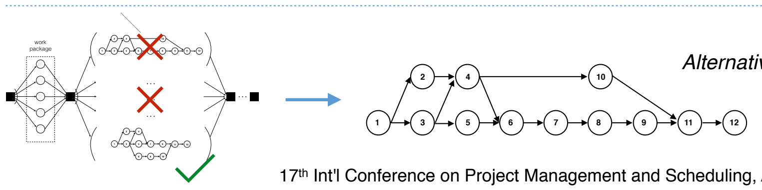
INTRODUCTION

Solution approaches

- Meta-heuristic solution approaches: solve both subproblems in a sequential/integrated way
  - Find best set of alternatives in the project structure
  - Rapidly generate high-quality schedule
  - Single best solution, but what about the non-selected alternatives?
- Construct a set of back-up schedules
  - Determine the best sets of alternatives in the project structure
  - Dynamically adjust the selected set of alternatives



Optimal project structure



Alternative project structure

GHENT UNIVERSITY

Operations Research & Scheduling

INTRODUCTION

Research questions

- Problem: Complex selection subproblem of RCPSP-AS
  - Large number of alternatives
  - Complex network of relations between alternatives
- Objective: Fix important options in order to limit the number of possible combinations

How can we identify important alternatives in the project structure?

INTRODUCTION

Research questions

- Problem: Complex selection subproblem of RCPSP-AS
  - Large number of alternatives
  - Complex network of relations between alternatives
- Objective: Fix important options in order to limit the number of possible combinations

How can we identify important alternatives in the project structure?

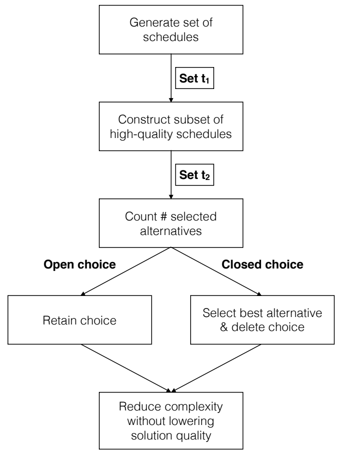
Main contributions

1. We present a technique to analyse the **impact of alternatives** on the solution quality of project instances
2. We define **two criteria** to analyse the set of generated solutions
3. We validate the proposed technique on both artificial project instances and **empirical case studies**

SOLUTION APPROACH

Step 1. Generate a set of high-quality solutions

- Construct the set of schedules by iteratively generating a single heuristic solution
- Use advanced and time-consuming exact procedures
- Metaheuristic procedure, e.g. Tabu Search algorithm



GHENT UNIVERSITY

Operations Research & Scheduling

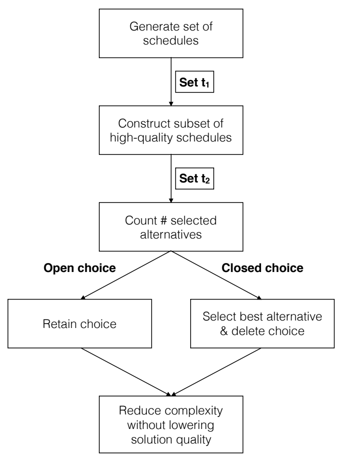
SOLUTION APPROACH

Step 1. Generate a set of high-quality solutions

- Construct the set of schedules by iteratively generating a single heuristic solution
- Use advanced and time-consuming exact procedures
- Metaheuristic procedure, e.g. Tabu Search algorithm

Step 2. Create a subset of the t_1 best schedules

- **Schedule diversity (t_1)**: The size of the subset determines the solution quality and diversity of the schedules



GHENT UNIVERSITY

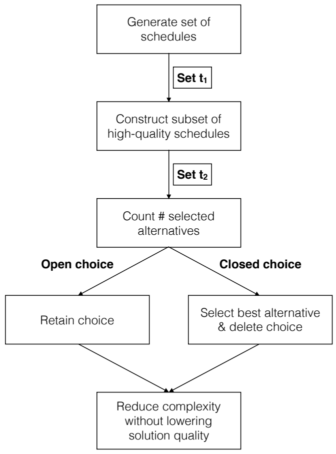
Operations Research & Scheduling

SOLUTION APPROACH

Step 1. Generate a set of high-quality solutions
- Construct the set of schedules by iteratively generating a single heuristic solution
- Use advanced and time-consuming exact procedures
- Metaheuristic procedure, e.g. Tabu Search algorithm

Step 2. Create a subset of the t_1 best schedules
- **Schedule diversity (t_1)**: The size of the subset determines the solution quality and diversity of the schedules

Step 3. Analyse the selected alternatives in subset t_1
- **Choice frequency (t_2)**: A preferred alternative is observed in at least t_2 schedules in the subset

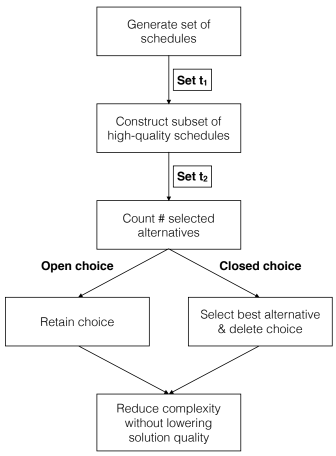


SOLUTION APPROACH

Step 1. Generate a set of high-quality solutions
- Construct the set of schedules by iteratively generating a single heuristic solution
- Use advanced and time-consuming exact procedures
- Metaheuristic procedure, e.g. Tabu Search algorithm

Step 2. Create a subset of the t_1 best schedules
- **Schedule diversity (t_1)**: The size of the subset determines the solution quality and diversity of the schedules

Step 3. Analyse the selected alternatives in subset t_1
- **Choice frequency (t_2)**: A preferred alternative is observed in at least t_2 schedules in the subset



Step 4. Identify important alternatives
- *Open choices* = No single alternative occurs significantly more than the others
- *Closed choices* = A single alternative is selected a sufficient number of times

Closed choices can be fixed in advance, while the selection for an open choice remains to be determined

SOLUTION APPROACH

The number of closed choices is impacted by…:

- Schedule diversity: As more diverse schedules (higher t_1) are considered, less choices will be closed
- Choice frequency: As a stricter threshold (higher t_2) is applied, less choices will be closed

GHENT UNIVERSITY

Operations Research & Scheduling

SOLUTION APPROACH

The number of closed choices is impacted by…:

- Schedule diversity: As more diverse schedules (higher t_1) are considered, less choices will be closed
- Choice frequency: As a stricter threshold (higher t_2) is applied, less choices will be closed

…and has an impact on…:

- **Complexity**: A higher number of closed choices will result in a lower complexity of the selection subproblem
- **Solution quality**: A higher number of closed choices will result in a lower solution quality

Closing choices implies a trade-off between a low complexity and a high solution quality

GHENT UNIVERSITY

Operations Research & Scheduling

SOLUTION APPROACH

The number of closed choices is impacted by…:

- Schedule diversity: As more diverse schedules (higher t_1) are considered, less choices will be closed
- Choice frequency: As a stricter threshold (higher t_2) is applied, less choices will be closed

…and has an impact on…:

- **Complexity**: A higher number of closed choices will result in a lower complexity of the selection subproblem
- **Solution quality**: A higher number of closed choices will result in a lower solution quality

Closing choices implies a trade-off between a low complexity and a high solution quality

…but we should also consider:

- **Variability**: The frequency of an alternative can only slightly exceed the threshold (i.e. low variability)
- **Strictness**: Choices can be closed very easily when the threshold is set very low (i.e. low strictness)
  ➡ Both increases the probability of mistakenly removing some choices from the search

RESULTS

Empirical case study analysis

- In practice, the scheduling problem might become highly complex
- Large number of feasible combinations of alternatives
- A focus on key choices allows to deal with large projects

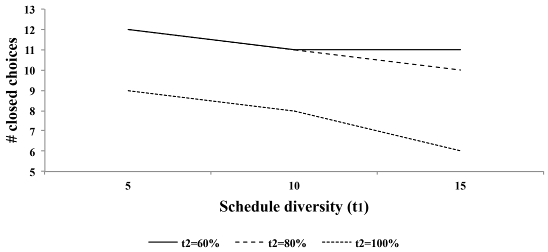
RESULTS

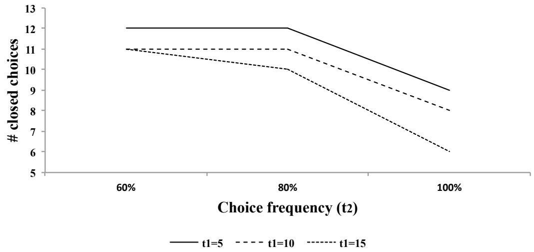
Empirical case study analysis

- In practice, the scheduling problem might become highly complex
- Large number of feasible combinations of alternatives
- A focus on key choices allows to deal with large projects

Schedule diversity (t_1) and choice frequency (t_2) are set (low, medium, high)

- There exists (sub)optimal alternative project structures that can be fixed with high certainty
- Project managers can focus attention on a low number of open choices
- **1/3 choices can be closed** despite high values of t_1 and t_2





RESULTS

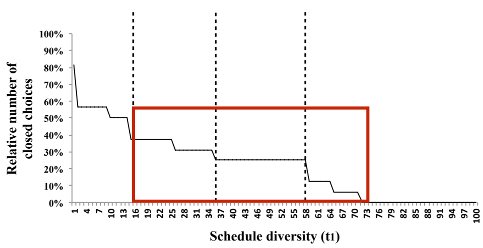
Empirical case study analysis

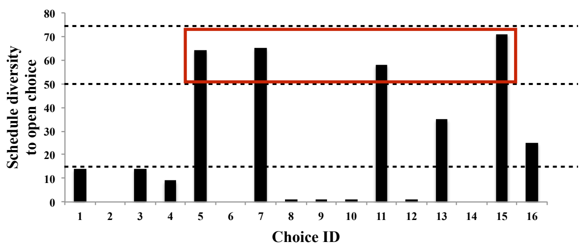
- In practice, the scheduling problem might become highly complex
- Large number of feasible combinations of alternatives
- A focus on key choices allows to deal with large projects

Robust choices = Choices that remain closed, independent of the (t_1 ,t_2) settings

- Most choices become open within the interval [low, high]
- Some choices only become open when t_1 >> high

We identify robust choices that can be fixed with great certainty





RESULTS

Empirical case study analysis

- In practice, the scheduling problem might become highly complex
- Large number of feasible combinations of alternatives
- A focus on key choices allows to deal with large projects

Types of choices: categorise each choice as one of **five** types of choices

- Most duration- and cost-related choices are closed
- Although many choices influence the activity sequence, most of these choices remain open

Activity sequence choices are harder to close and thus crucial to resolve in the selection subproblem

Schedule diversity	**Types of choices**	**Choice frequency** $t_2 = 60\%$	$t_2 = 80\%$	$t_2 = 100\%$
$t_1 = 15$	Duration	4/4	4/4	3/4
	Cost	2/3	2/3	2/3
	Resources	1/2	0/2	0/2
	Non-implementation	3/3	3/3	1/3
	Activity sequence	1/4	1/4	0/4
$t_1 = 10$	Duration	4/4	4/4	4/4
	Cost	2/3	2/3	2/3
	Resources	1/2	1/2	0/2
	Non-implementation	3/3	3/3	2/3
	Activity sequence	1/4	1/4	0/4
$t_1 = 5$	Duration	4/4	4/4	4/4
	Cost	3/3	3/3	2/3
	Resources	1/2	1/2	1/2
	Non-implementation	3/3	3/3	2/3
	Activity sequence	1/4	1/4	0/4

RESULTS

Artificial analysis

- We validate the generic approach on a large set of artificial projects
- The number of closed choices indeed decreases as t_1 and t_2 increase
- The relative number of closed choices is lower compared to the empirical analysis
- The number of closed choices does not drastically change for different settings in contrast to case study analysis.

Key trends are observed, but harder to identify preferred choices due to the balanced data generation procedure

CONCLUSIONS

Can we identify important alternatives in the project structure?

Yes…

- 1/3 choices can be closed, which is interesting for large projects
- Identify robust choices that can be fixed with high certainty
- Identify properties of choices that are easier/harder to close
- Validate the proposed generic procedure for both empirical and artificial data

But…

- Manage the trade-off between computational complexity and solution quality
- Beware of the impact of (1) Variability and (2) Strictness

***Objective*: focus on key choices during project scheduling and control without sacrificing project performance**

FACULTY OF ECONOMICS AND BUSINESS ADMINISTRATION

BUSINESS INFORMATICS AND OPERATIONS MANAGEMENT

dr. Tom Servranckx
Post doctoral researcher

BUSINESS INFORMATICS AND OPERATIONS MANAGEMENT

Universiteit Gent
@ugent
Ghent University

tom.servranckx@ugent.be
www.ugent.be