Analysing the impact of alternative network structures on resource-constrained schedules: Artificial and empirical experiments, Computers and Industrial Engineering, Tom Servranckx, Mario Vanhoucke* and Giel Vanhouwaert.

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Results for project N°2

Analysis of population

In figure 1a, we represent a set of 100 schedules for project 2 subdivided by the project makespan and we plot the absolute number of solutions with a fitness value lower than or equal to a certain project makespan in figure 1b. Both figures show that an increase of t_1 will diversify the set of schedules without significantly increasing the project makespan as long as t_1 does not exceed a certain threshold (i.e. $t_1 > 30$).
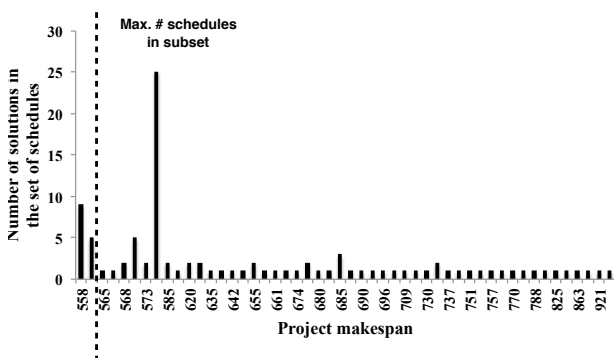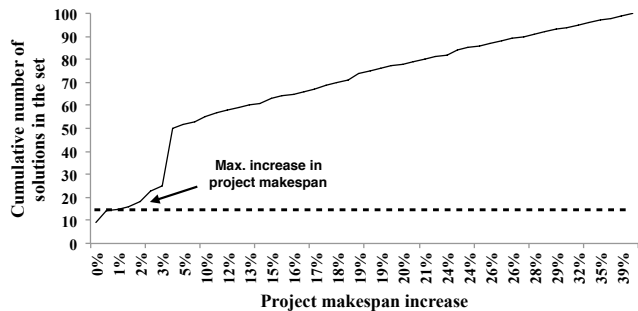

Figure 1a

Figure 1b

Schedule diversity and choice frequency

In figure 2a, we observe that - in general - the number of closed choices decreases as t_1 increases. In case that t_1=15, however, we observe that the number of closed choice increases compared to a lower value of t_1. When the t_2 threshold increases, we see that this effect disappears and we even observe a linear decrease in case that t_2=100%. In figure 2b, the number of closed choices decreases as t_2 increases, independent of the value for threshold t_1. These observations are confirmed in figure 3, where we present a detailed analysis of the frequency of the alternatives for each choice in project 2.
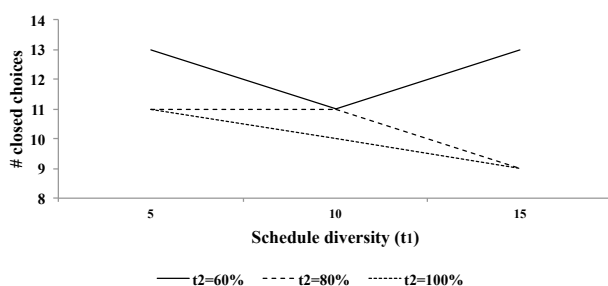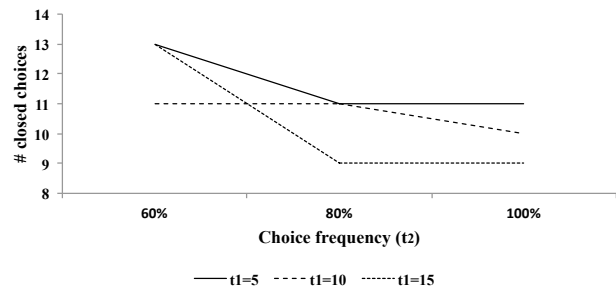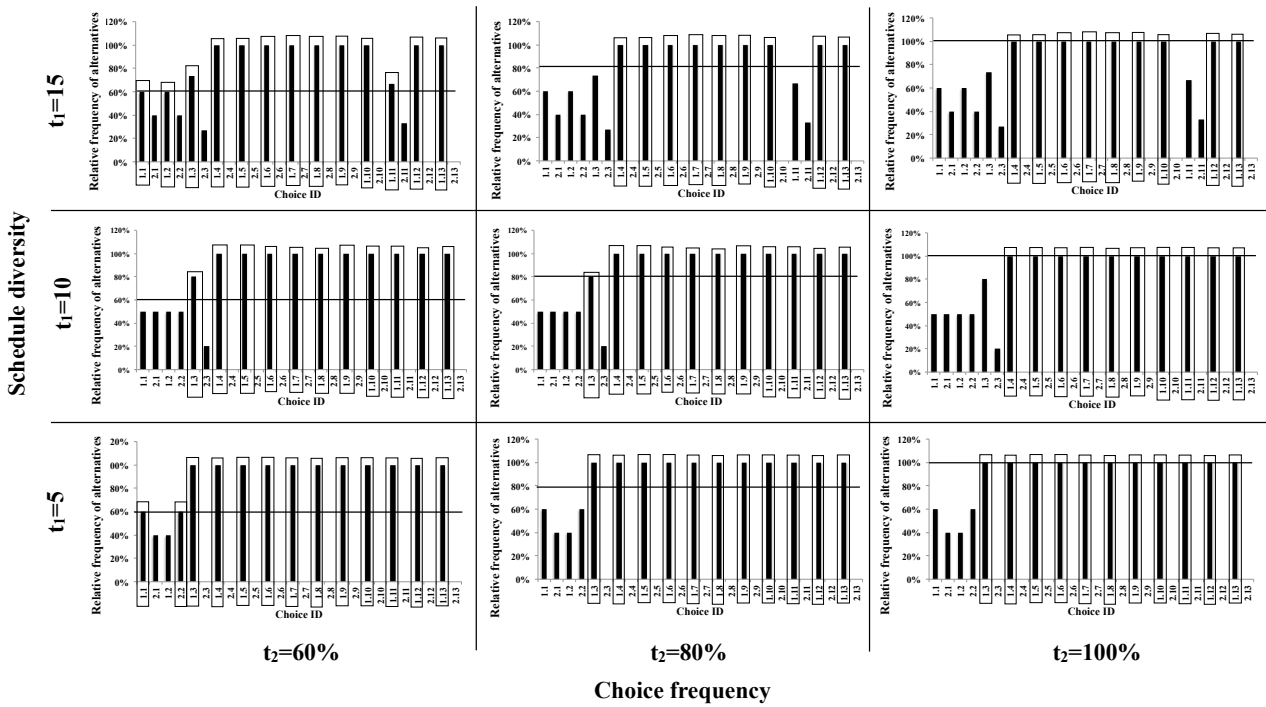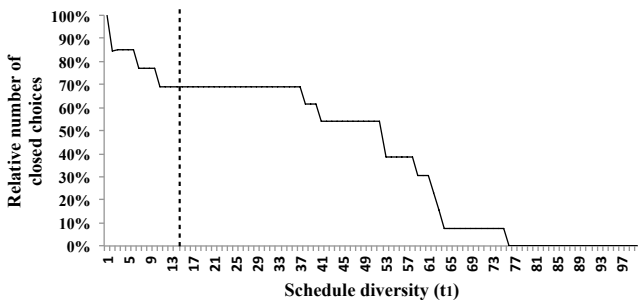

Figure 2a

Figure 2b

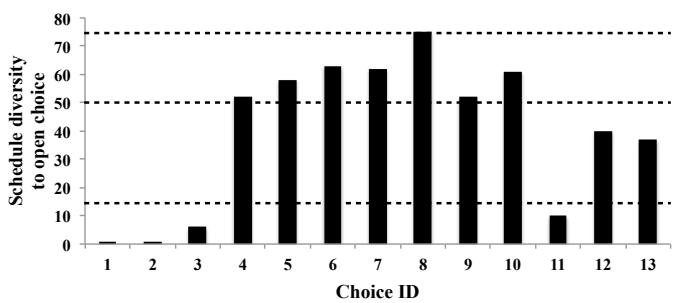## Closed choices for different values of t_1 and t_2

Figure 3

Robust choices

In figure 4a, we observe that there are no closed choices for project 2 when $t_1 > 77$ (given that $t_2 = 100\%$). As a result, the value of threshold t_1 can be increased in practice to ensure that the decisions for closing choices are made using a larger subset of schedules, however, this subset should never contain more than 77 schedules. In order to identify robust choices, figure 4b shows the required schedule diversity to open each choice. We observe that most choices are very robust as they are only opened when $t_1 > 50$.

Figure 4a

Figure 4b

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Types of choices

In table 1, we show the relative number of closed choices per choice type for each value of t_1 and t_2. First of all, we observe that the different choices are equally distributed over the different choice types. Secondly, almost all duration, cost and non-implementation types of choices are closed in our analysis, even for high values of t_1 and t_2.

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

Table 1

Results for project N°3

Analysis of population

For project 3, we again notice that a subset of t_1 schedules can be diversified without a large increase in project makespan (see figure 5a). In contrast to the other two projects, however, there exist more alternative schedules that result in the same project makespan in this project. This can also be observed by the quasi-linear increase of the curve in figure 5b, which implies that no single project makespan is dominant in the set of generated schedules.
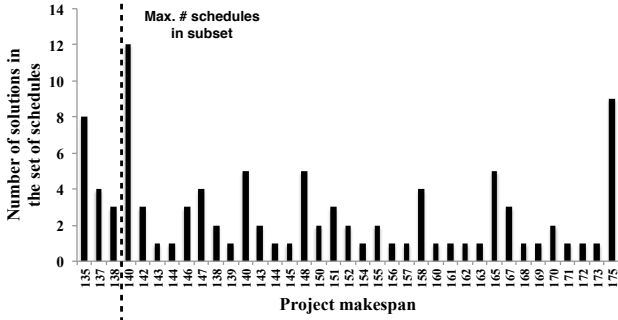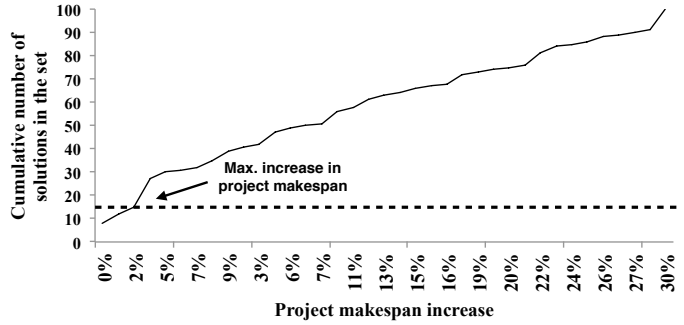

Figure 5a

Figure 5b

Schedule diversity and choice frequency

Although that the number of closed choices remains the same as the value of threshold t_1 increases in figure 5a for t_2=60%, we observe a decrease in the number of closed choices for the larger values of t_2. Figure 5b shows a clear decrease of the number of closed choices for increasing values of t_2 given different values of t_1. Figure 6 presents the number of closed choices for different values of t_1 and t_2 in more detail.
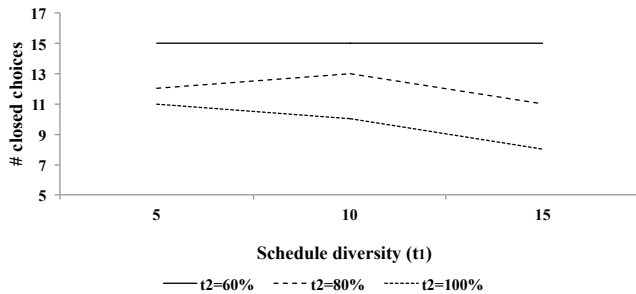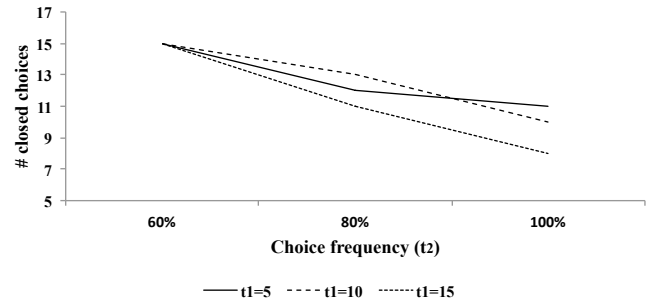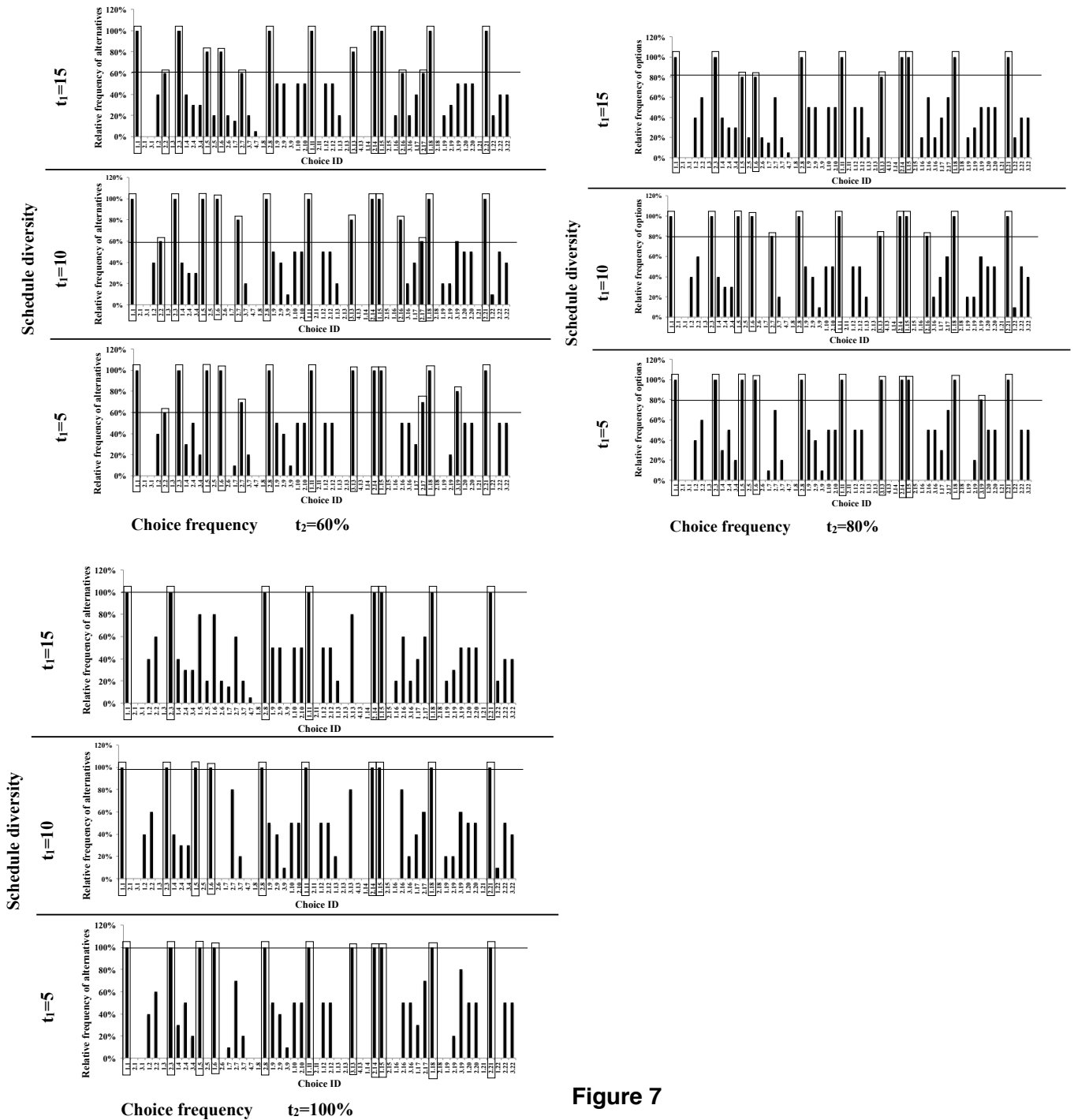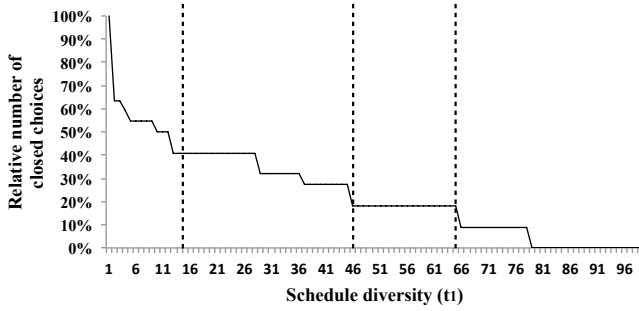

Figure 6a

Figure 6b

*Closed choices for different values of t₁ and t₂*

Figure 7

Robust choices

In figure 8a, we notice that the relative number of closed choices decreases drastically as the schedule diversity is increased up to $t_1=15$ and stabilises around 30% for $t_1=[15,45]$ and around 20% for $t_1=[45,65]$. Furthermore, we observe that there are no closed choices for project 3 when $t_1>81$ (given that $t_2=100\%$).

Compared to the two other projects, the robustness of the choices highly differs between the choices in project 3. The number of robust choices is also relatively low since only choices 14, 15 and 18 (see figure 8b) will change from closed to open when the schedule diversity is higher than $t_1=50$.

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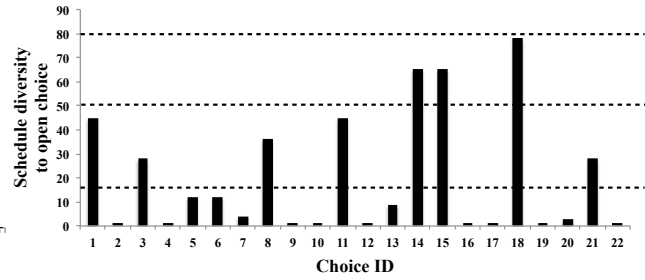
Figure 8a

Figure 8b

Types of choices

With respect to the types of choices, the duration and cost types of choices are considered as one choice type as well as there exist no resource and activity sequence types of choices in this project (see table 2). As a result, most of the choices are classified as duration- or cost-related choices. The results provide no indication that one of the two types of choices has a higher relative number of closed choices for different values of t_1 and t_2.

Schedule diversity	Types of choices	Choice frequency		
		$t_2 = 60\%$	$t_2 = 80\%$	$t_2 = 100\%$
$t_1 = 15$	Duration Cost	9/13	6/13	5/13
	Resources	0/0	0/0	0/0
	Non-implementation	6/9	5/9	3/9
	Activity sequence	0/0	0/0	0/0
$t_1 = 10$	Duration Cost	9/13	8/13	6/13
	Resources	0/0	0/0	0/0
	Non-implementation	6/9	5/9	4/9
	Activity sequence	0/0	0/0	0/0
$t_1 = 5$	Duration Cost	9/13	7/13	6/13
	Resources	0/0	0/0	0/0
	Non-implementation	6/9	5/9	5/9
	Activity sequence	0/0	0/0	0/0

Table 2