Uncertainty in building times

IDENTIFYING CRITICAL FACILITIES IN A DYNAMIC LOCATION PROBLEM

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Outline

- Motivation
- Mathematical Models
- Algorithmic approaches
- Future work

Motivation

In most dynamic location models described in the literature, there are binary variables that represent “When” and “Where” to open facilities:

$$y_{it} = \begin{cases} 1, \text{ if facility } i \text{ is opened at period } t \\ 0, \text{ otherwise} \end{cases}$$

But have we really the power to decide **when** facilities are opened?

theguardian

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Sport › Football ›

Fifa issues u Brazil Worl

- Curitiba's Arena d
- Labour force to be

Jonathan Watts in Rio d
The Guardian, Wednesda

The Fifa secretary genera... situation is not ideal. The stadium is very delayed and well outside the delivery schedule to ensure best use by the Fifa World Cup.' Photograph: /Reuters

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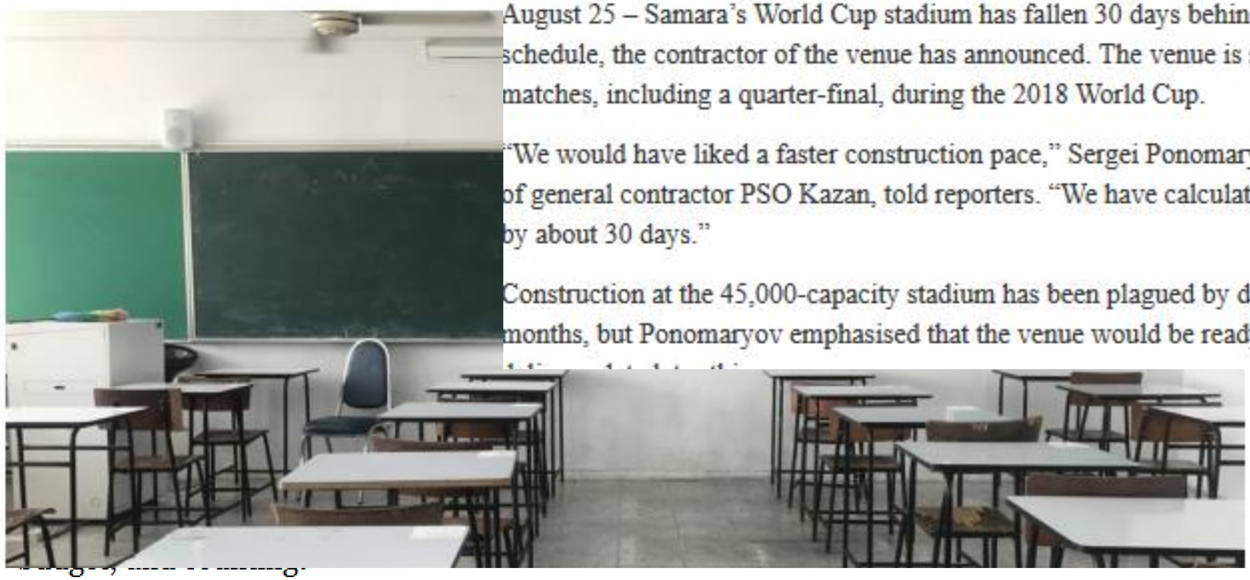
Fredericton High year

Classes were to resume on Sept. 5,

CBC News Posted: Sep 01, 2017 10:54 AM AT |



INSIDE WORLD FOOTBALL

20 September 2017 GMT: 10:03

Samara World Cup stadium behind schedule, but builder says it will meet year-end deadline

25th August 2017

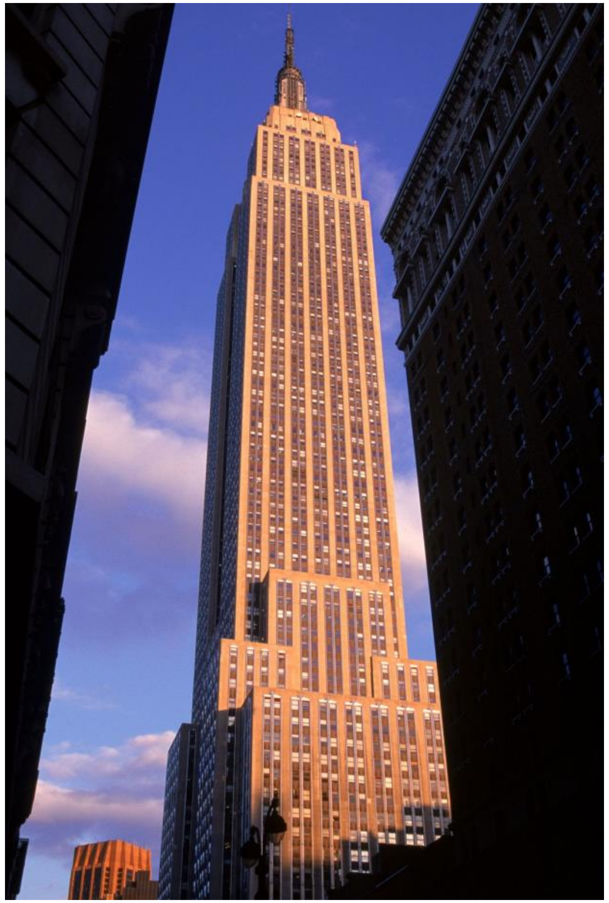
August 25 – Samara's World Cup stadium has fallen 30 days behind its construction schedule, the contractor of the venue has announced. The venue is set to host six matches, including a quarter-final, during the 2018 World Cup.

"We would have liked a faster construction pace," Sergei Ponomaryov, the deputy head of general contractor PSO Kazan, told reporters. "We have calculated that we are behind by about 30 days."

Construction at the 45,000-capacity stadium has been plagued by delays over the past months, but Ponomaryov emphasised that the venue would be ready by the time of the

, but as Building revealed
he tech giant's planned

Well, sometimes we can get ahead of schedule...



The Empire State buildind was completed 3 months ahead of schedule!

Construction Management and Economics, 1985, 3, 171–181

Reasons for delays in public projects in Turkey

DAVID ARDITI[1], GUZIN TARIM AKAN[2] and SAN GURDAMAR[2]
[1]*Department of Civil Engineering, Illinois Institute of Technology, Chicago, Illinois 60616, USA*
[2]*Formerly with Department of Civil Engineering, Middle East Technical University, Ankara, Turkey*

ELSEVIER
International Journal of Project Management
Volume 25, Issue 5, July 2007, Pages 517–526

Causes and effects of delays in Malaysian construction industry

Murali Sambasivan, Yau Wen Soon

Proceedings of the 17th International Symposium on Advancement of Construction Management and Real Estate
2014, pp 715-720

The Causes of Delays in the Delivery of Construction Projects: A Review of Literature

X. Shivambu, Wellington Didibhuku Thwala

Interfaces
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Prev Volume 11 Issue 5, October 1981, pp. 66-70 Next

Why Projects Are “Always” Late: A Rationale Based on Manual Simulation of a PERT/CPM Network

Richard J. Schonberger
Department of Management, University of Nebraska—Lincoln, Lincoln, Nebraska 68588,

Motivation

- Opening a new facility implies, most of the times, some pre-opening works: building, licensing, buying materials, building infrastructures, and so on...
- There are many sources of possible delays...
- Many times expected timings are not fulfilled...
  - Poor design
  - Weather
  - Financial conditions
  - Equipment/material availability
  - ...
- Uncertainty is, many times, neglected.

The problem

- So, are we capable of deciding when to open or….
- …are we only able to decide **when we should begin carrying out the necessary activities to prepare the facility to be opened**?

- If there is no uncertainty associated with the time it gets to carry out all the needed activities before having a facility up and running, then these two problems are equivalent.

The problem

- A planning horizon
- A set of potential locations for facilities
- A set of customers that have to be assigned to an opened facility in each time period
- Fixed opening and maintenance costs
- Assignment costs
- “Building” times for each facility
- Scenarios that represent the uncertainty associated with problem’s parameters

Mathematical model

$$y_{it} = \begin{cases} 1, & \text{if facility } i \text{ begins to be built in period } t \\ 0, & \text{otherwise} \end{cases}$$

$$x_{ijts} = \begin{cases} 1, & \text{if client } j \text{ is assigned to facility } i \text{ in period } t \text{ under scenario } s \\ 0, & \text{otherwise} \end{cases}$$

Uncapacitated problem

$$Min \sum_{i=1}^{I}\sum_{t=1}^{T}\sum_{s=1}^{S} p_s f_{its} y_{it} + \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{t=1}^{T}\sum_{s=1}^{S} p_s c_{ijts} x_{ijts}$$

Minimization of total expected cost.

Probability associated with scenario *s*

Subject to:

$$\sum_{i=1}^{I} x_{ijts} = 1, \forall j,t,s$$

All clients will be assigned to open facilities in each time period and under all possible scenarios.

$$\sum_{t=1}^{T} y_{it} \leq 1, \forall i$$

A facility starts to be built at most once during the planning horizon.

$$x_{ijts} \leq \sum_{\tau=1}^{t-d_{is}} y_{i\tau}, \forall i,j,s, 1+d_{is} \leq t \leq T$$

A client is only assigned to a facility if that facility is already operational (the building time has elapsed).

$$x_{ijts} \in \{0,1\}, \forall i,j,t,s \; ; y_{it} \in \{0,1\}, \forall i,t$$

Uncapacitated problem

- As it is, it is only possible to have a feasible solution if there is at least one facility already in operation in the beginning of the planning horizon.
- If this is not the case, it will be necessary to consider a setup time during which clients do not have to be assigned to facilities.

Capacitated problem

- It is not possible to assure that the total demand will be always fulfilled under all scenarios for all time periods, unless it would be possible to fulfill with the already opened facilities under all scenarios.
- It is necessary to explicitly consider a cost associated with the possibility of not satisfying all the demand.

Capacitated problem

x_{ijts} = percentage of client j's demand that is assigned to facility i under scenario s

δ_{jts} = percentage of client j's demand that is not being satisfied in period t

Capacitated problem

$$Min \sum_{i=1}^{I}\sum_{t=1}^{T}\sum_{s=1}^{S} p_s f_{its} y_{it} + \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{t=1}^{T}\sum_{s=1}^{S} p_s c_{ijts} D_{jts} x_{ijts} + \sum_{j=1}^{J}\sum_{t=1}^{T}\sum_{s=1}^{S} p_s c'_{jts} D_{jts} \delta_{jts}$$

Expected cost of not fulfilling completely the clients' demands

Subject to:

$$\sum_{i=1}^{I} x_{ijts} + \delta_{jts} = 1, \forall j, t \geq T_0, s$$

Demand does not have to be totally satisfied.

$$\sum_{j=1}^{J} x_{ijts} \leq C_{it} \sum_{\tau=1}^{t-d_{is}} y_{i\tau}, \forall i, j, s, 1+d_{is} \leq t \leq T$$

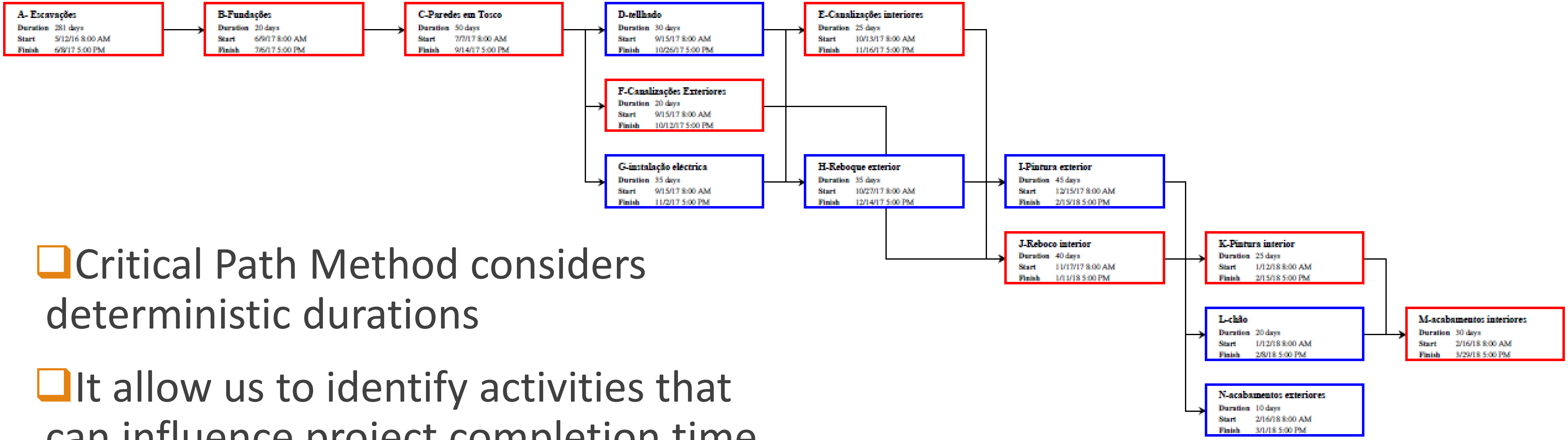
The capacity of the existing facilities cannot be exceeded.

$$\sum_{t=1}^{T} y_{it} \leq 1, \forall i$$

Critical facilities

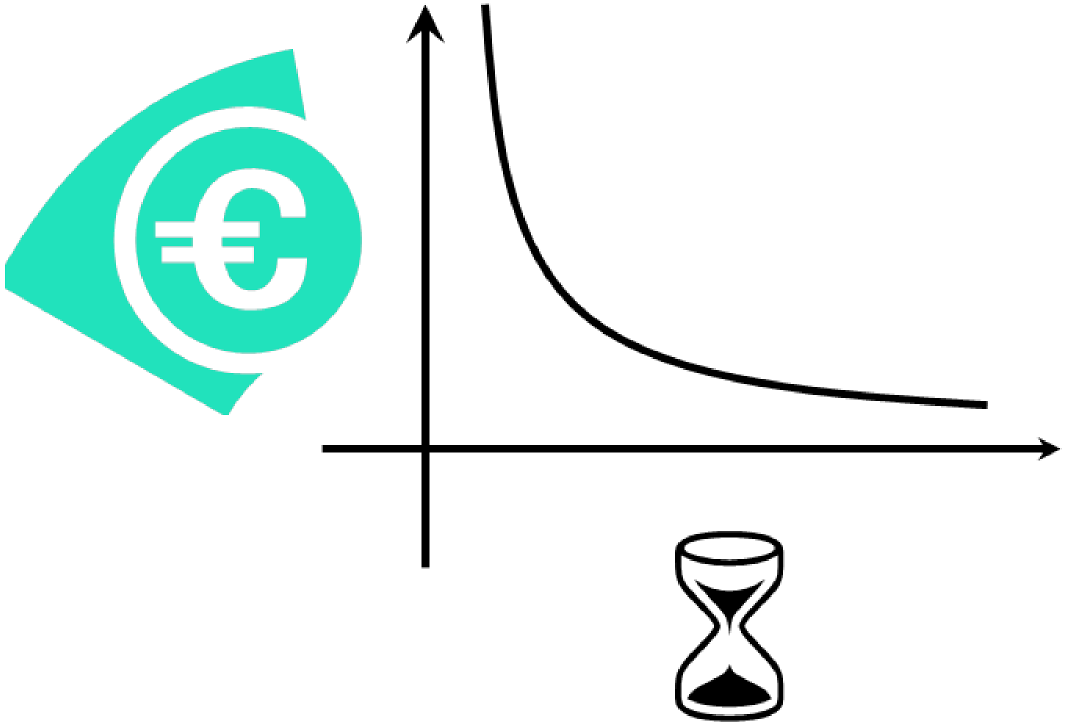
- Considering uncertainty in building times, does it make sense to try to identify “critical facilities”?
- Critical facilities can be defined as being the ones in which it is important to guarantee that building times are as short as possible under all possible scenarios.

Critical Activities



- Critical Path Method considers deterministic durations
- It allow us to identify activities that can influence project completion time

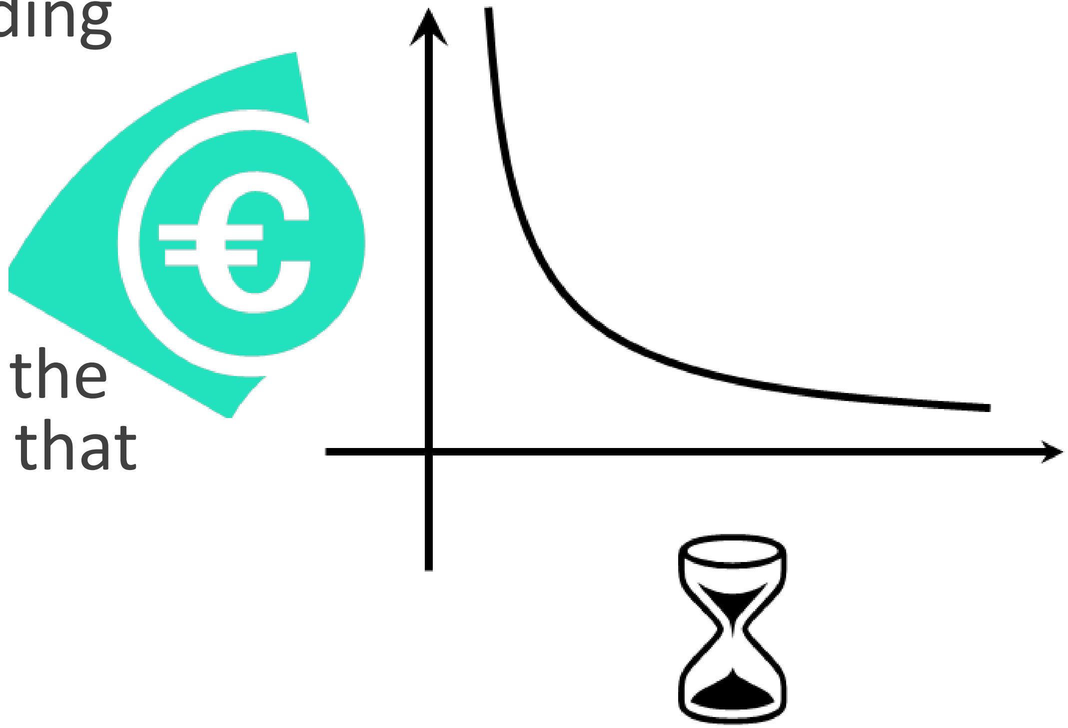
Critical Activities



Critical facilities

- Will it be worth to invest in some facilities in order to reduce the uncertainty associated with their building times?

- If it is, then these facilities can be considered “critical” in the sense that the decision maker is willing to guarantee that they will be operational as soon as possible, at a cost.



Critical facilities

$$g_{it} = \begin{cases} 1, & \text{if facility } i \text{ begins to be built in period } t \text{ and} \\ & \text{an additional investment is made} \\ 0, & \text{otherwise} \end{cases}$$

$$d'_{is} = \text{building time associated with facility } i \text{ under scenario } s$$

Critical facilities

$$d'_{is} = d_{is}(1 - g_{it}) + d_{i\min} g_{it}, \forall i, t, s$$

$$g_{it} \le y_{it}, \forall i, t$$

$$x_{ijts} \le \sum_{\tau=1}^{t-d'_{is}} y_{i\tau}, \forall i, j, s, 1 + d_{is} \le t \le T$$

Critical facilities

$$d'_{is} = d_{is}(1 - g_{it}) + d_{i\min} g_{it}, \forall i, t, s$$

$$g_{it} \le y_{it}, \forall i, t$$

Instead of only two possible building times, a linear relation between time and cost can be considered, or several different time values for different levels of investment.

$$\tau + d'_{is} \ge t + \xi - M z_{i\tau ts}, \forall i, \tau = 1, \ldots T, t \ge \tau, s$$

$$\tau + d'_{is} \le t + M(1 - z_{i\tau ts}), \forall i, \tau = 1, \ldots T, t \ge \tau, s$$

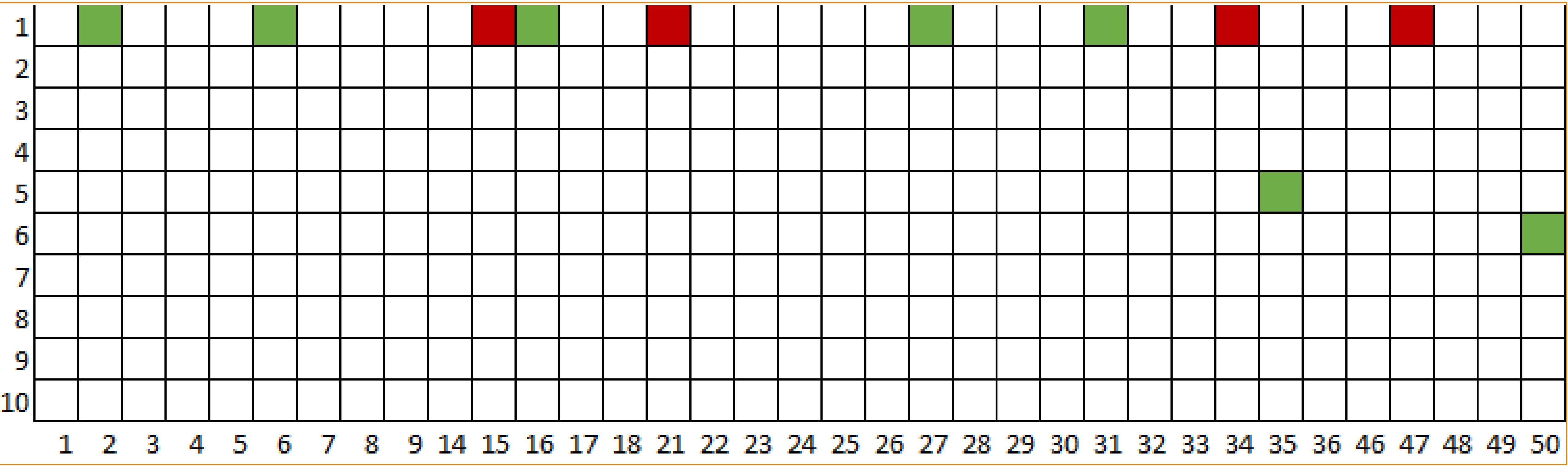
Determine when it is the earliest ***t*** period facility ***i*** can be operational under scenario ***s***, if it has started to be built in τ.

$$z'_{i\tau ts} \le \frac{z_{i\tau ts} + y_{i\tau}}{2}, \forall i, \tau = 1, \ldots, T, t \ge \tau, s$$

Determines whether facility ***i*** can be operational in ***t*** under scenario ***s***, if it has started to be built in τ.

$$x_{ijts} \le \sum_{\tau=1}^{t} z'_{i\tau ts}, \forall i, j, s, t$$

All clients will be assigned to operational facilities only in each time period and under all possible scenarios.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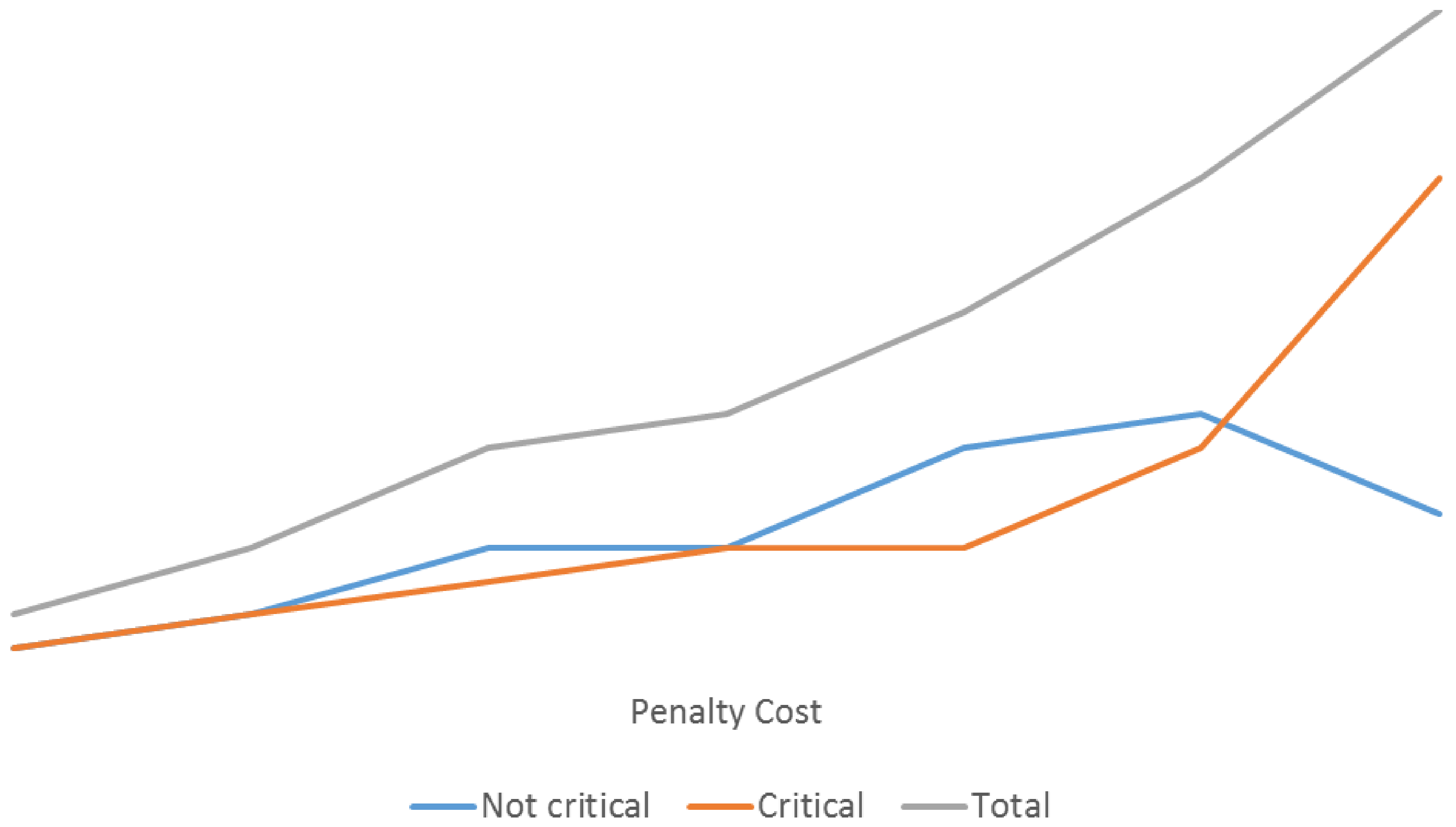
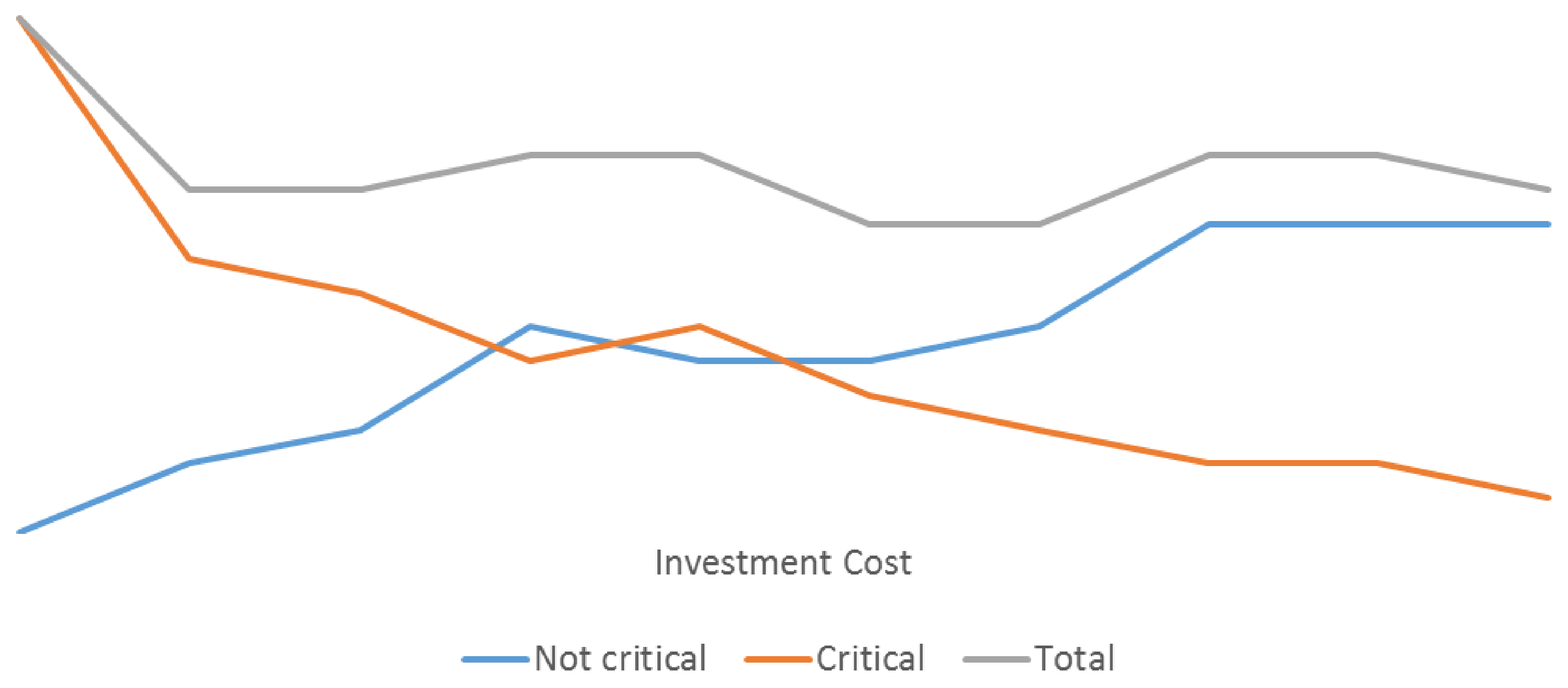
Critical facilities

- Different values for the additional investment cost will lead to different solutions and identification of different critical facilities
  - If investment cost is equal to zero, all facilities will be considered critical...
- The choice of which facilities to consider critical will depend on the relationship between the additional investment cost and the cost of not being able to fulfill all the demand.
  - Changing the corresponding values will lead to the discovery of the existing compromises between these two costs

Investment cost>0; increasing penalty costs



Penalty cost >0; increasing investment costs



Algorithmic approaches

- Uncapacitated problems
  - Primal-dual heuristics

Algorithmic approaches

- Uncapacitated problems
  - Primal-dual heuristics

$$Max \sum_j \sum_t \sum_s v_{jts} - \sum_i u_i$$

subject to:

$$v_{jts} - w_{ijts} \leq p_s c_{ijts}, \forall i, j, t, s$$

$$\sum_i \sum_s \sum_{\tau = t + d_{is}} w_{ij\tau s} - u_i \leq \sum_s p_s f_{its}, \forall i, t$$

$$w_{ijts} \geq 0; u_i \geq 0$$

Algorithmic approaches

- Uncapacitated problems
  - Primal-dual heuristics
- Capacitated problems
  - Heuristics
- Critical facilities
  - Heuristics

Other Models

- Closing/Reopening of facilities
- Allowing for demand backlog
  - Being able to satisfy the demand later, at a cost
- Capacity expansion

On-going and Future Work

- Extensive computational experiments to compare the primal-dual heuristic with a general solver (CPLEX)
- Implementation of (other) metaheuristics for the capacitated cases and the identification of critical facilities
- Generate problems where delays are independent and where delays are correlated
- Consideration of different objective functions
  - Minimization of the maximum regret
  - Multiobjective approaches

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