Seminar 'Optimization under Uncertainty'

robust, stochastic, and online optimization

Marie Schmidt

17.04.2024

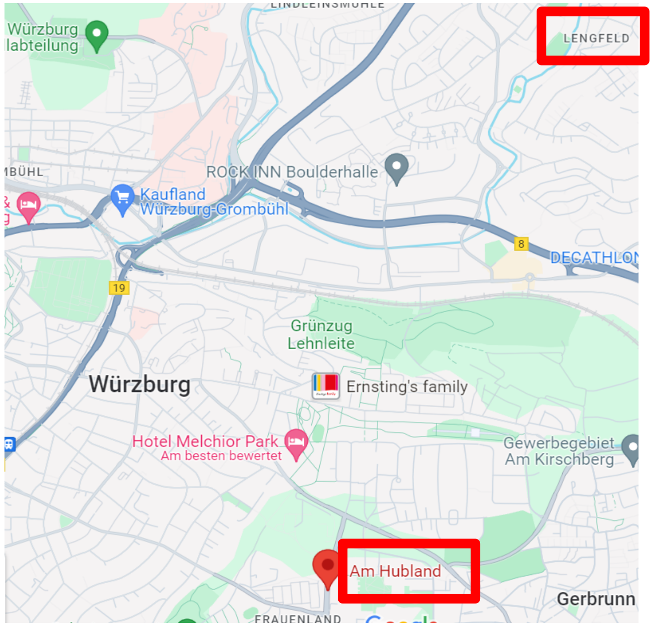
Agenda for today

- Course language?
- What's this course about?
- Administrative stuff

Course language

- English or German for presentations and course communication?
- reports can be in English or German

The fastest way to work



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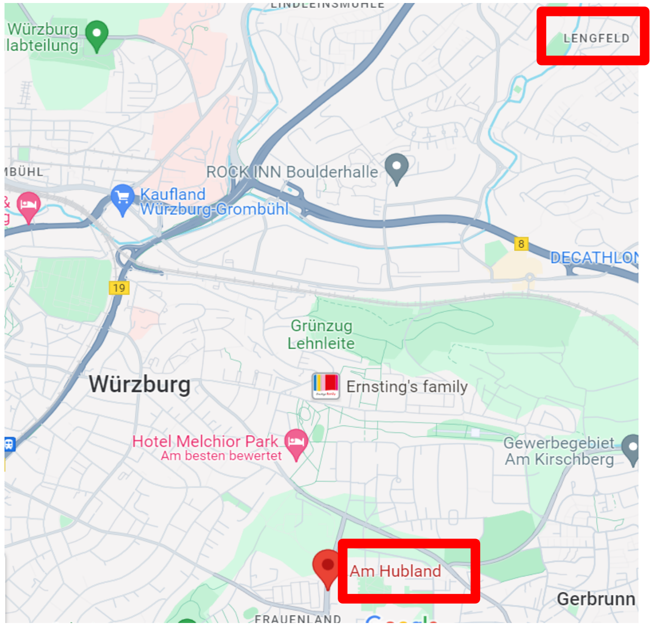

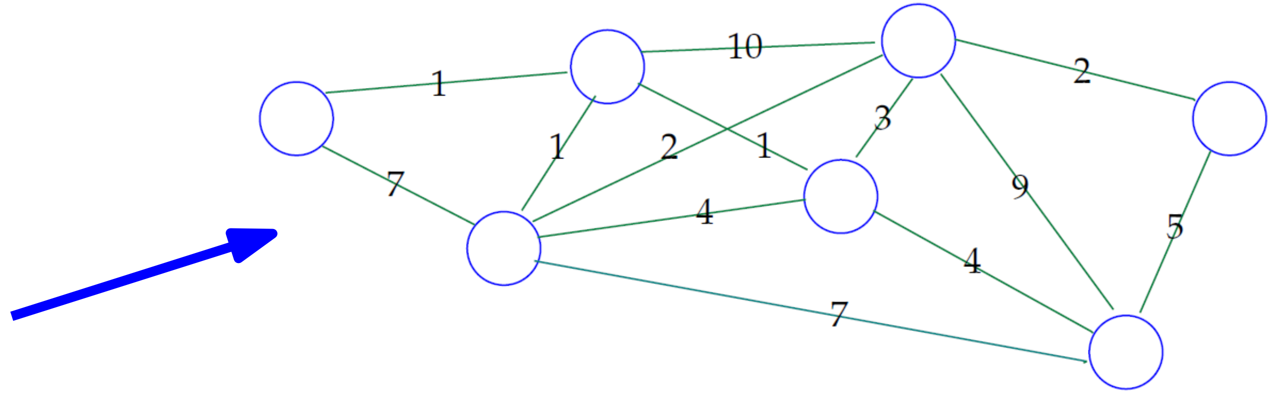

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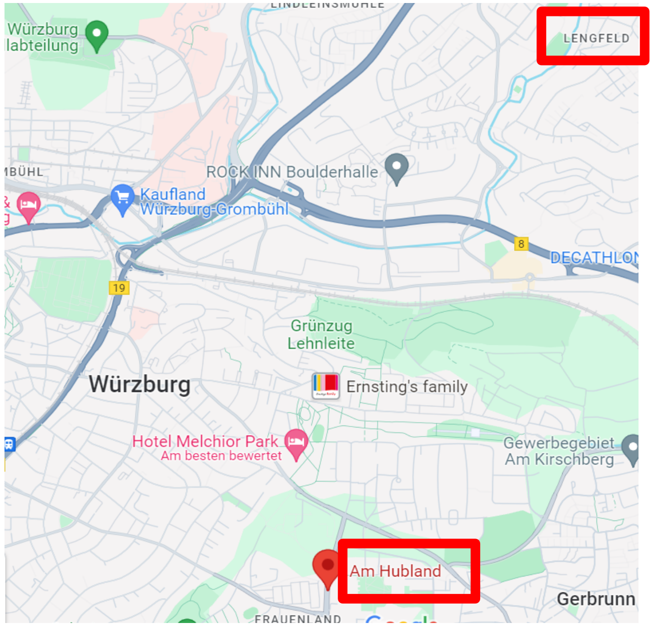

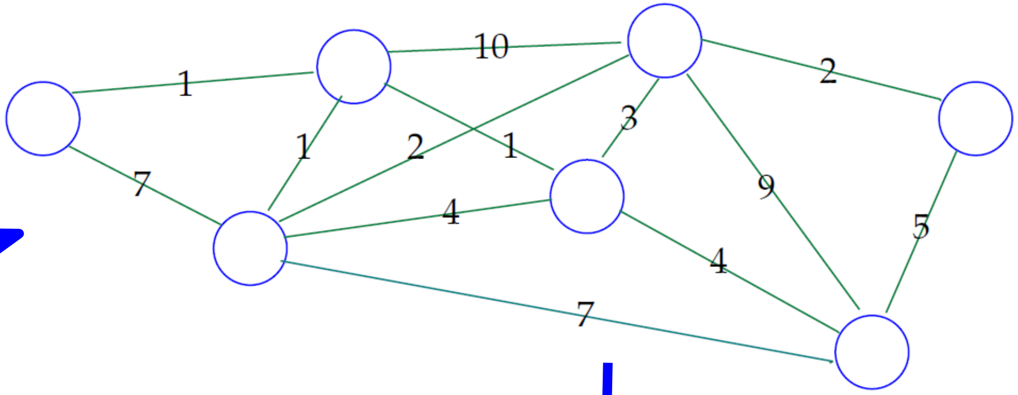

Input: (positively) Weighted Graph G, Vertex s
Output: Shortest Paths from s

```
INITIALIZE(G, s)
Q = new PriorityQueue(V, d)
while not Q.Empty() do
    u = Q.ExtractMin()
    for v ∈ Adj[u] do
        RELAX(u, v; w)
    end for
    u.color = white
end while
```

```
function RELAX(u, v; w)
    if v.d > u.d + w(u, v) then
        v.color = grey
        v.d = u.d + w(u, v)
        v.π = u
        Q.DecreaseKey(v, v.d)
    end if
end function
```

```
function INITIALIZE(G, V)
    for u ∈ V do
        u.color = white
        u.d = ∞
        u.π = None
    end for
end function
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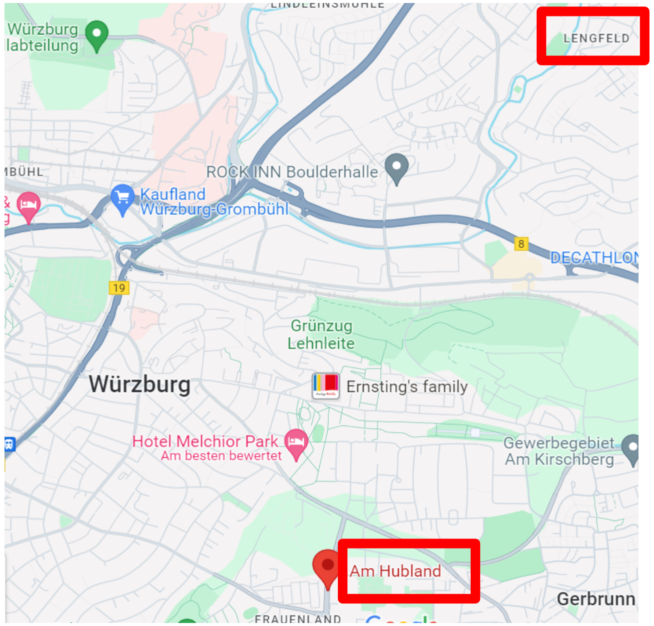

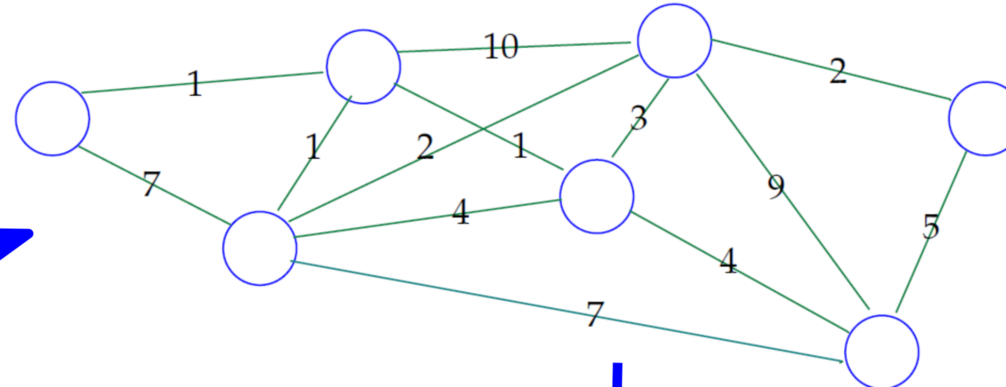

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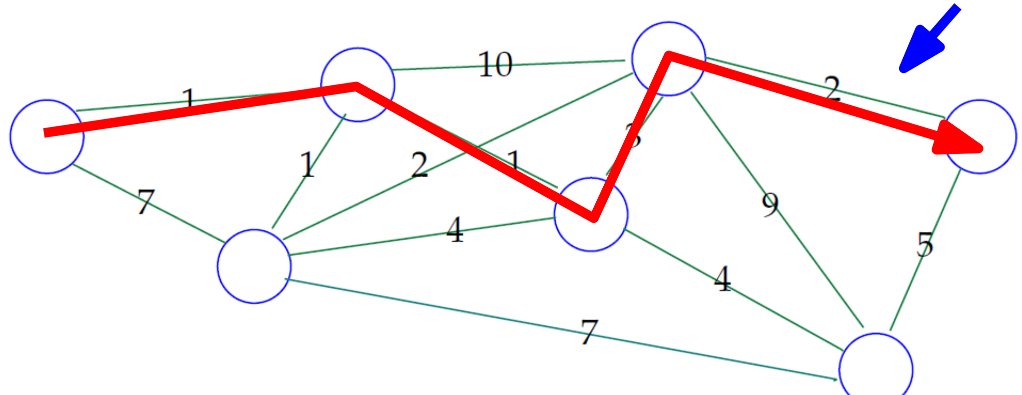

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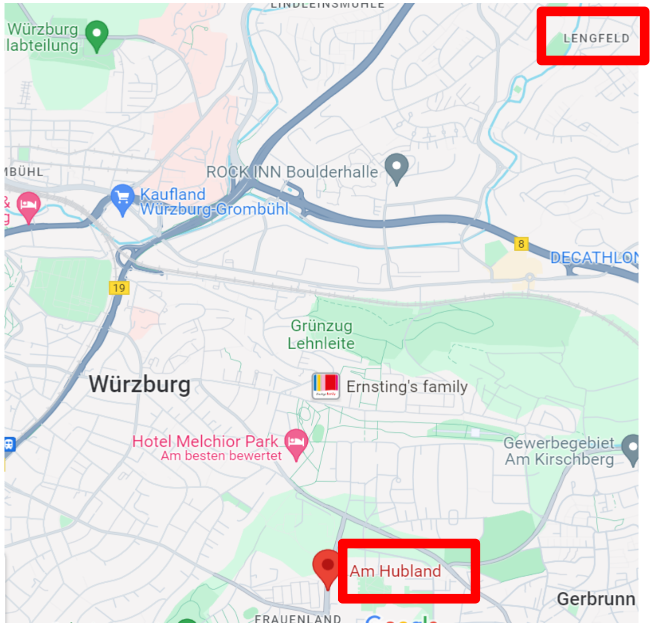

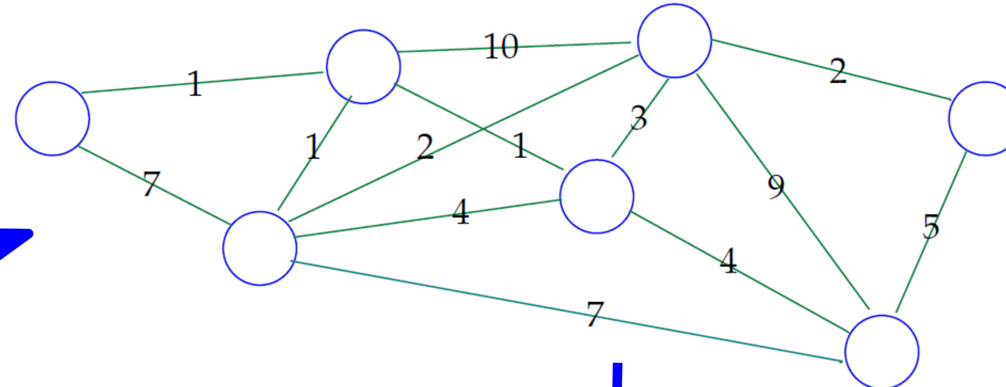

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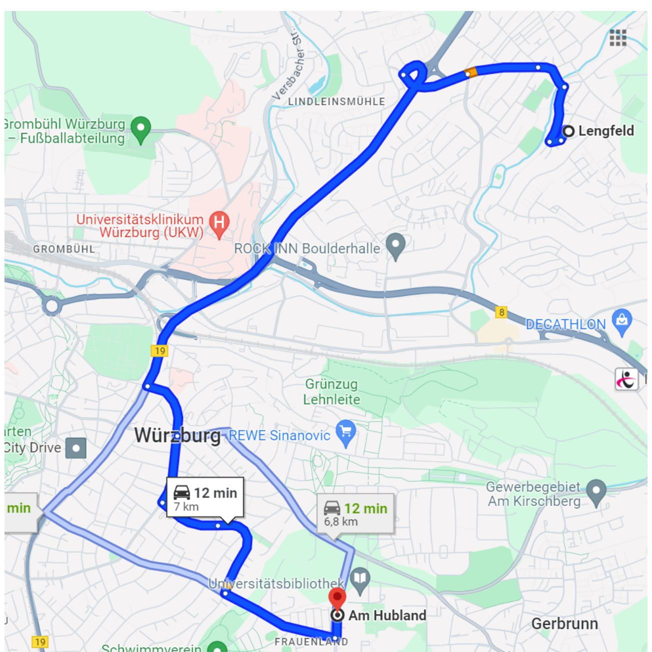
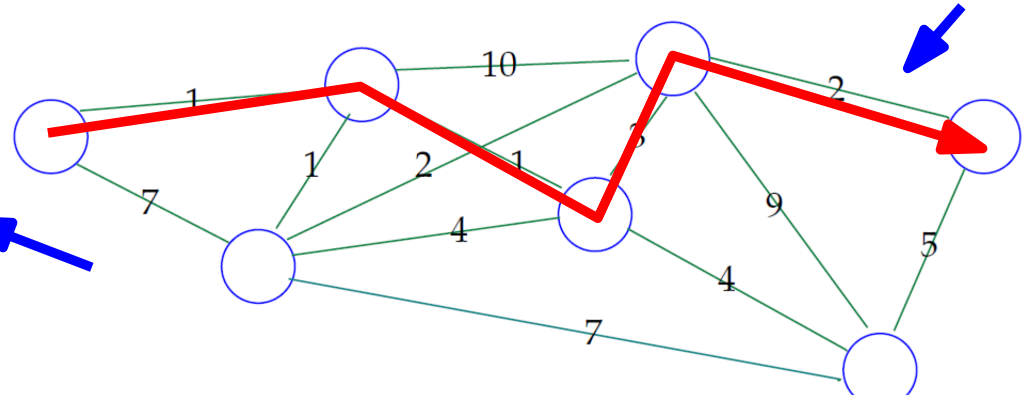
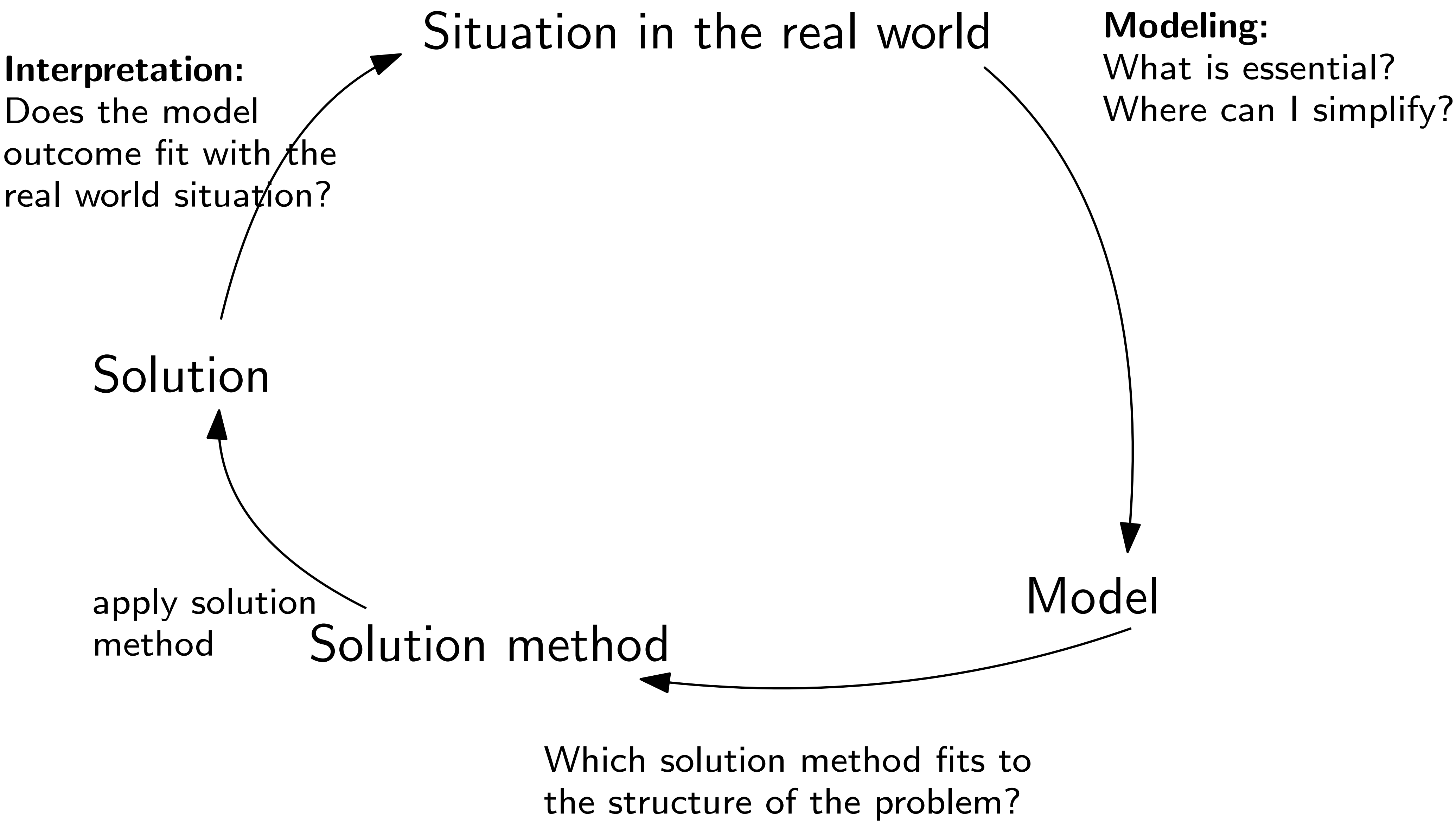




Modeling cycle for optimization problems



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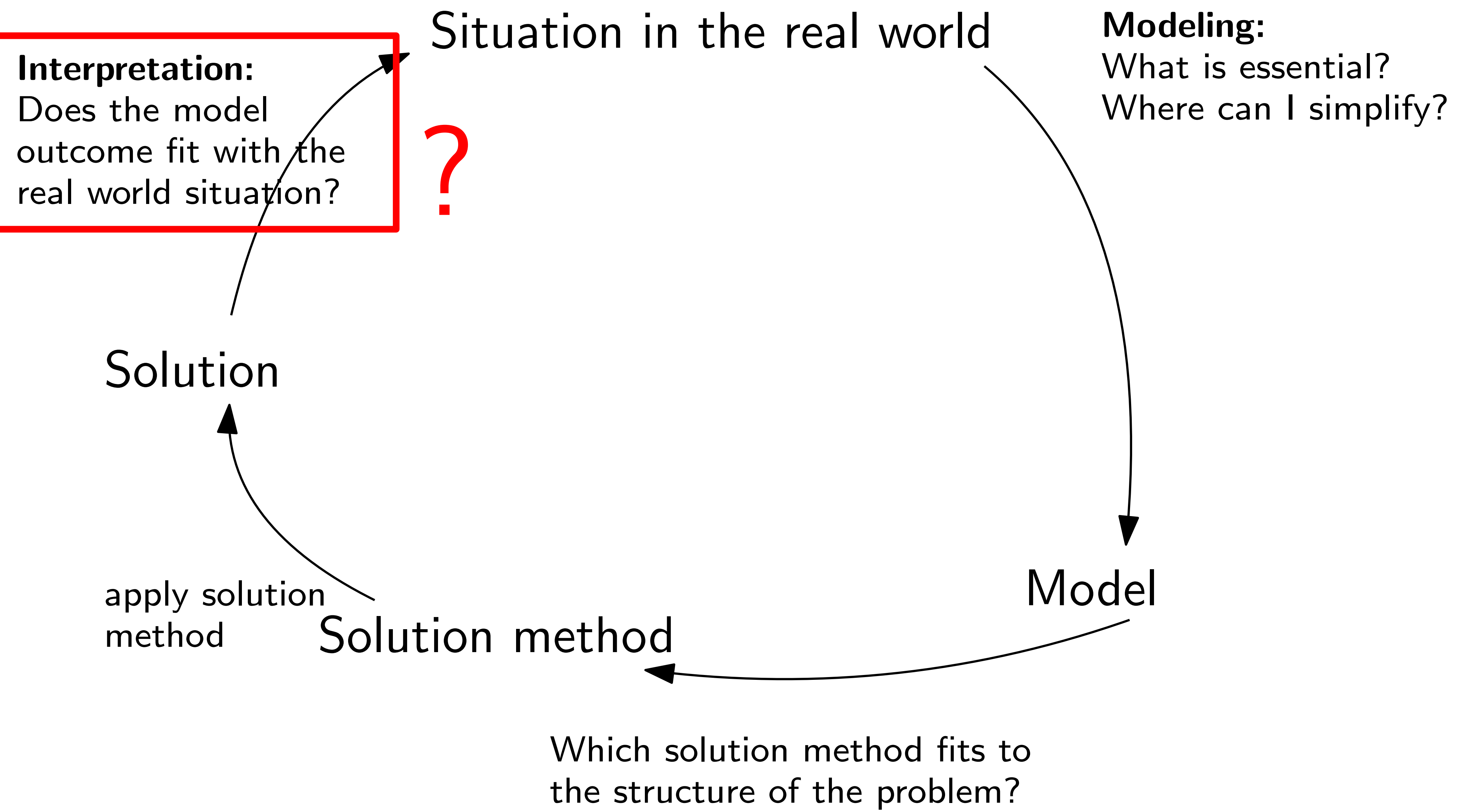

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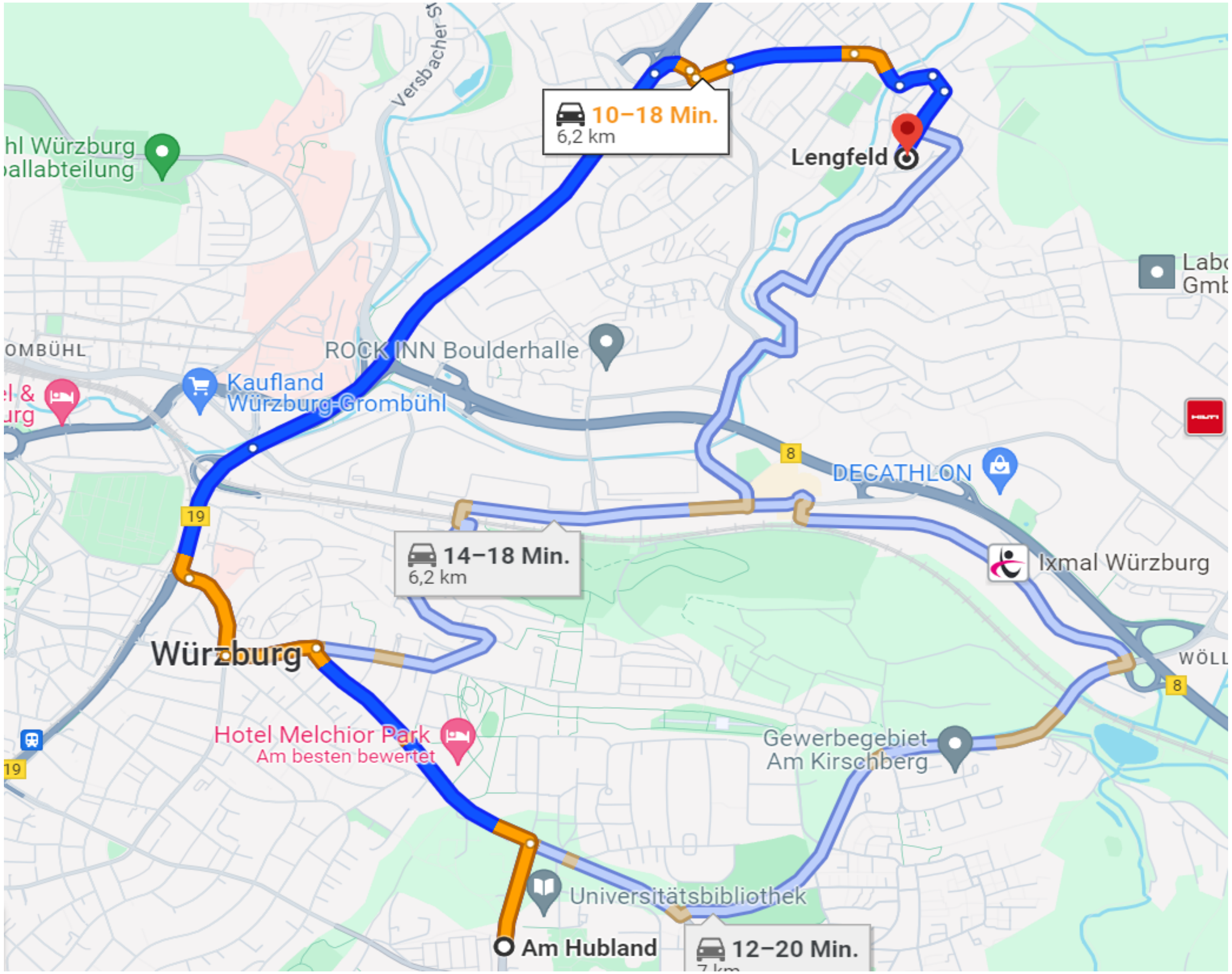

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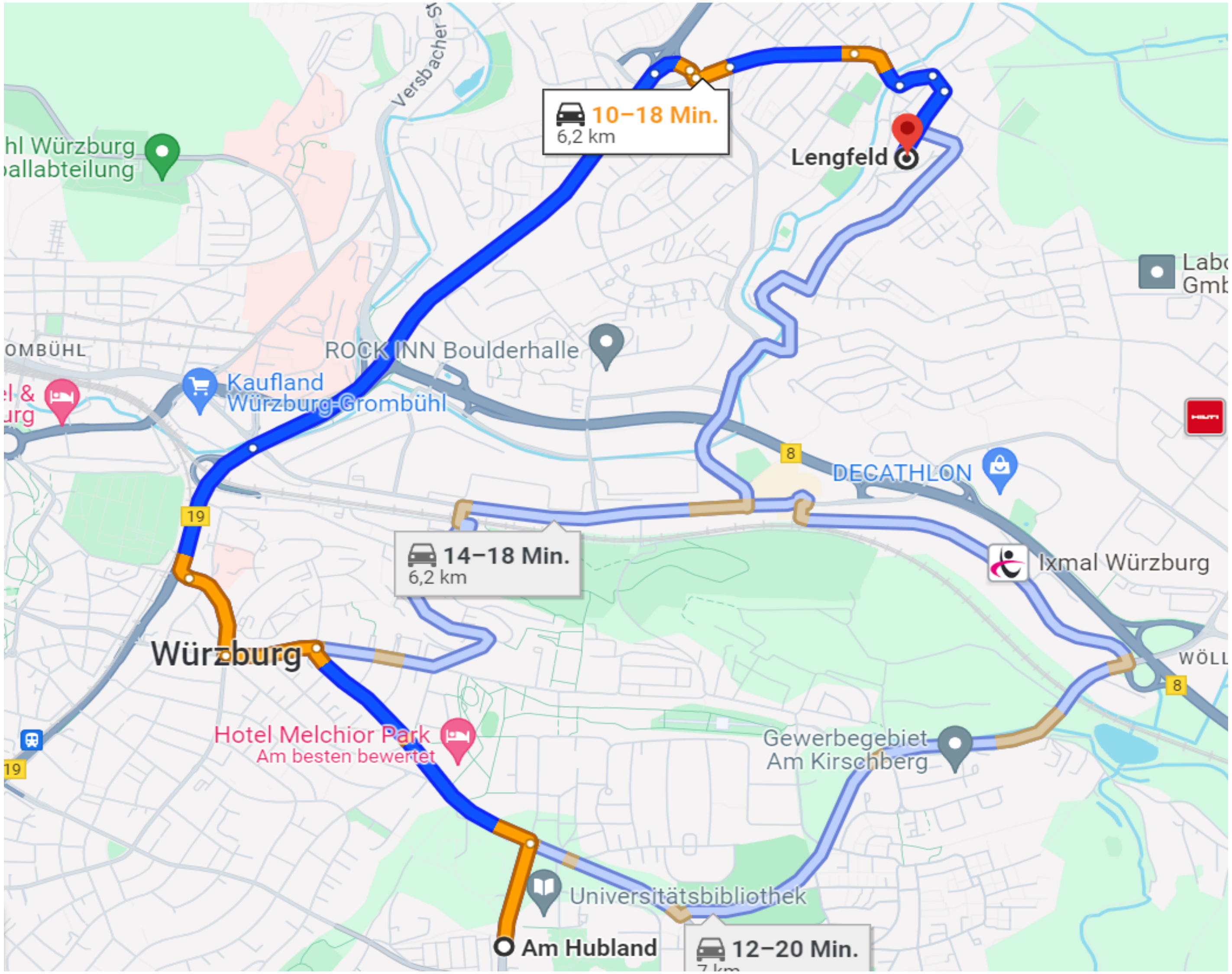
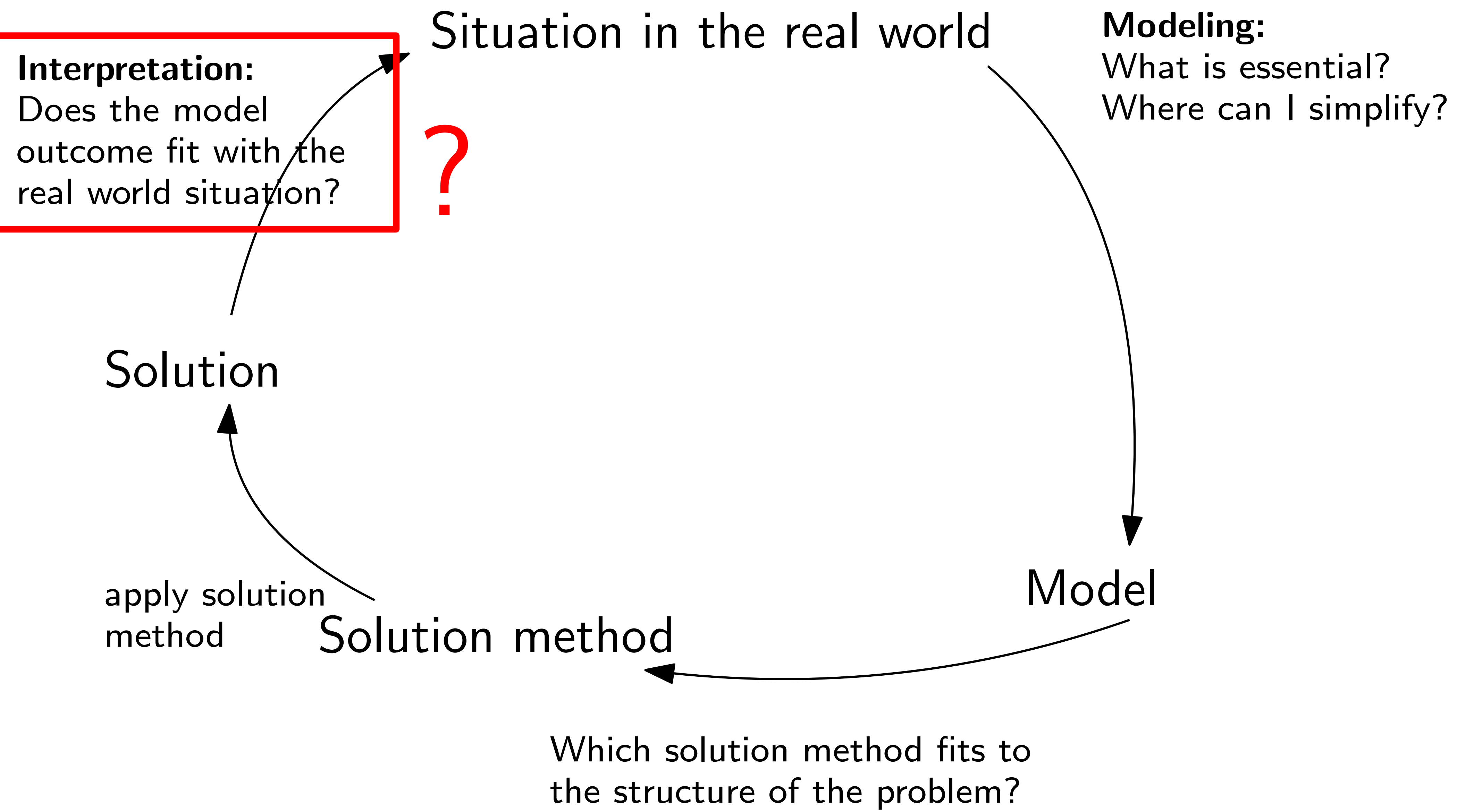


→ variation in the driving times leads to different routes

Modeling cycle for optimization problems



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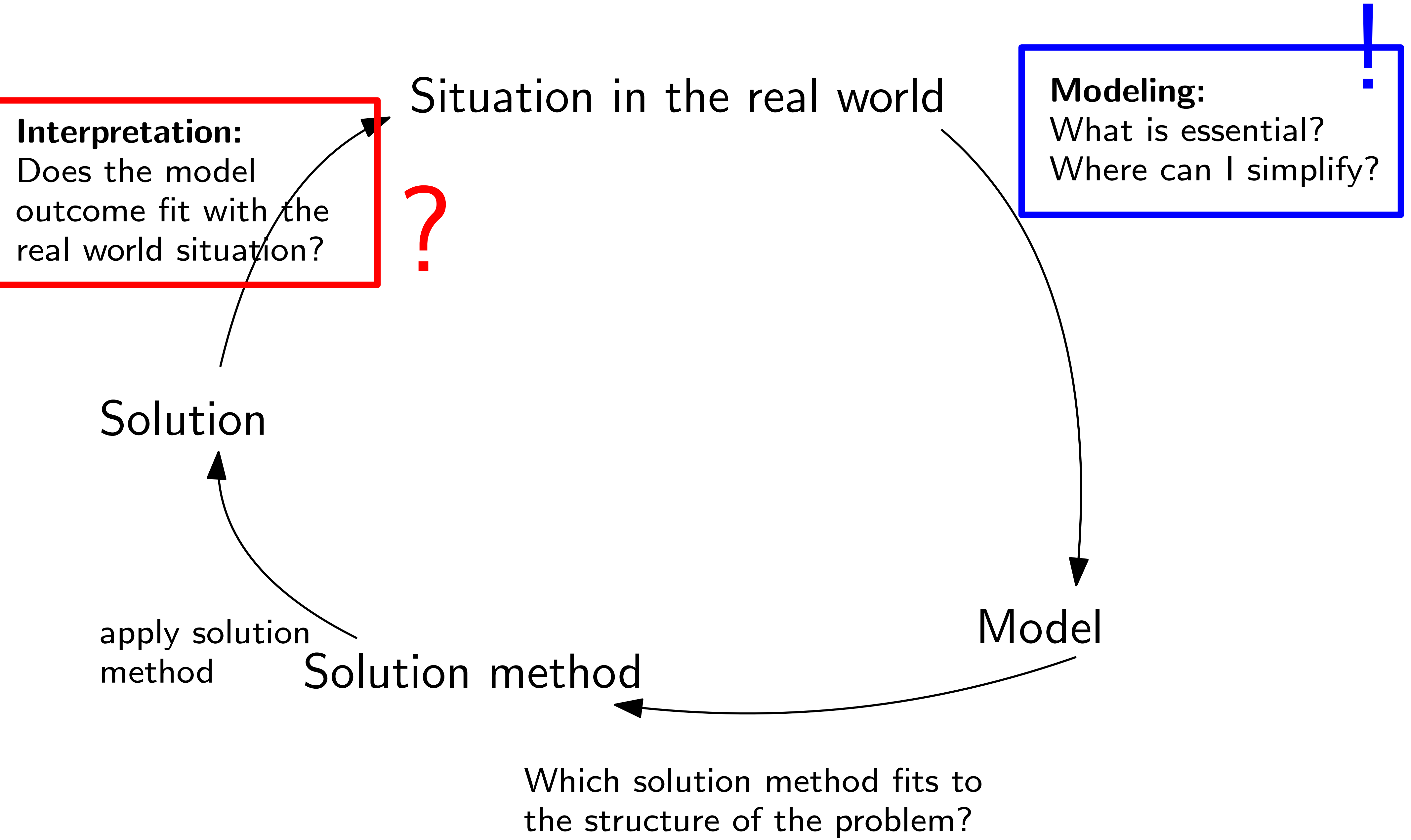

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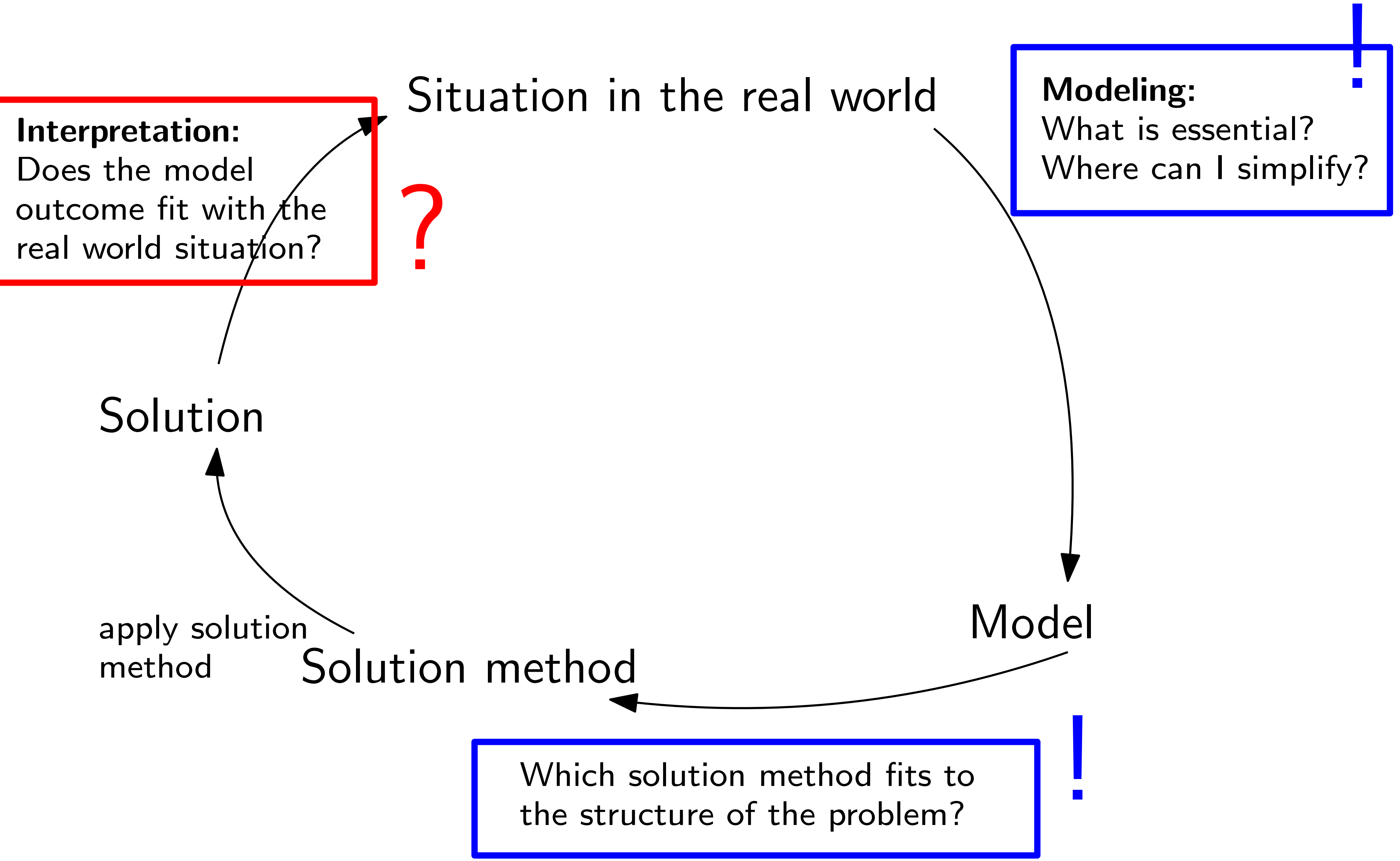

Seminar questions

How can we formulate optimization problems, when we do not have exact information on input parameters?

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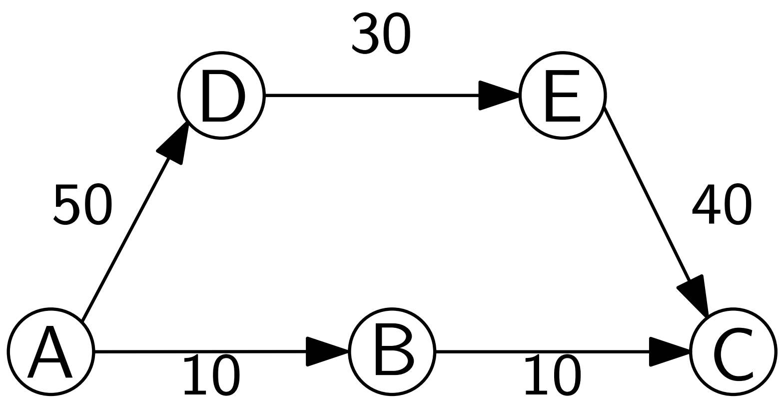
How can we find solutions to such optimization problems?

Example: The traveler's route choice problem



What is the best way from A to C?

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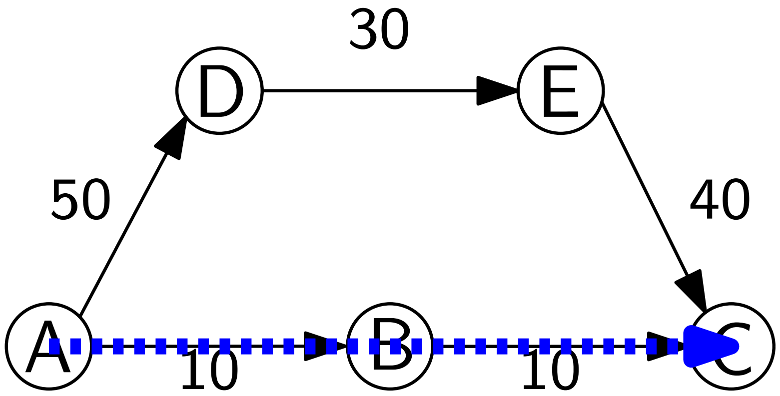

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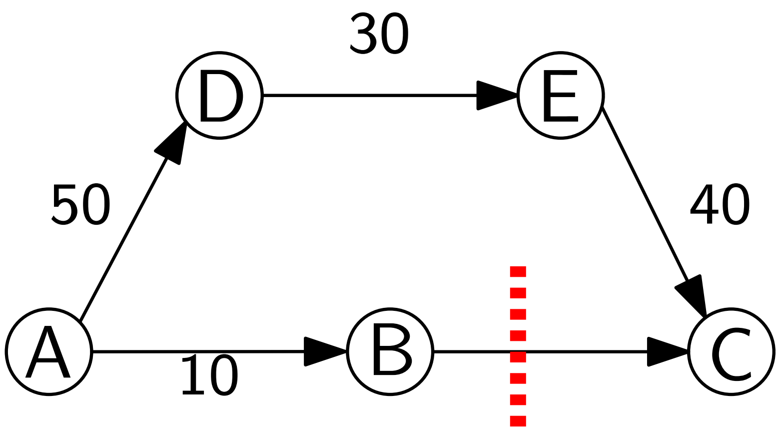

What is the best way from A to C
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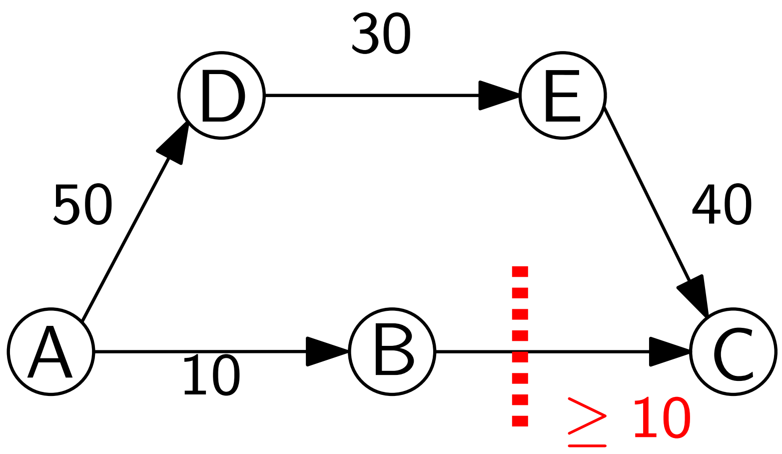

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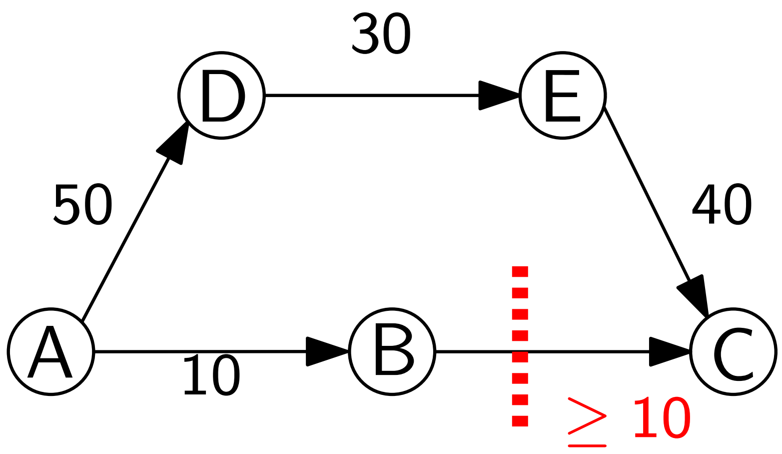

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What should the traveler do?

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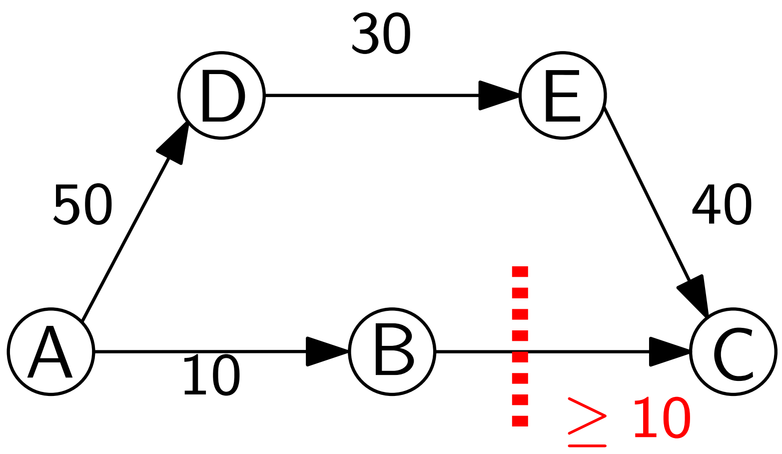

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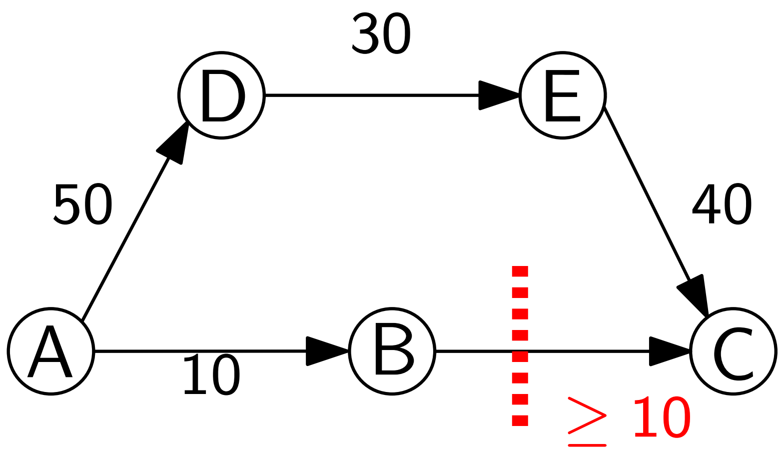

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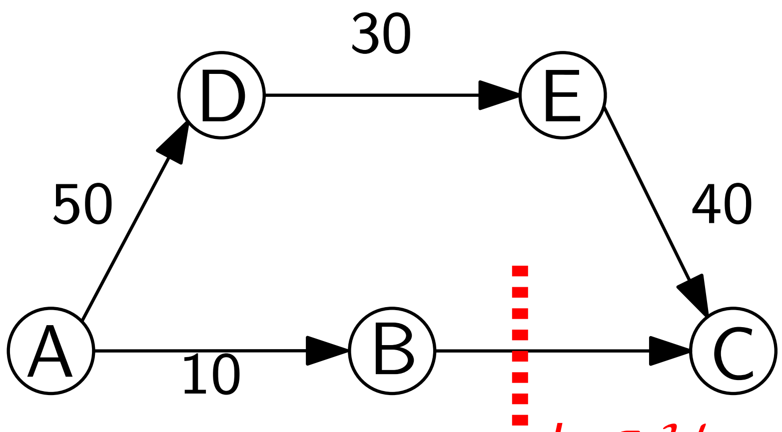

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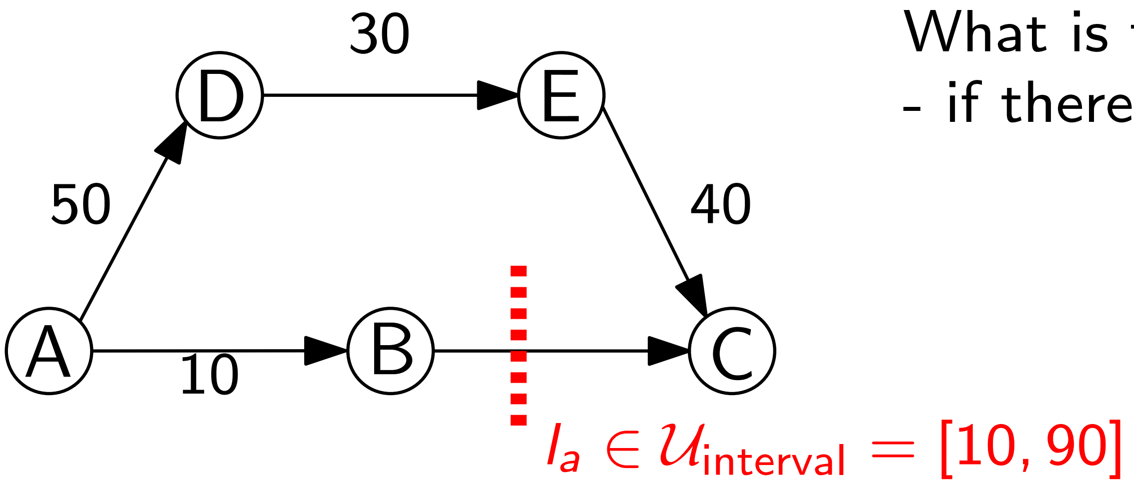

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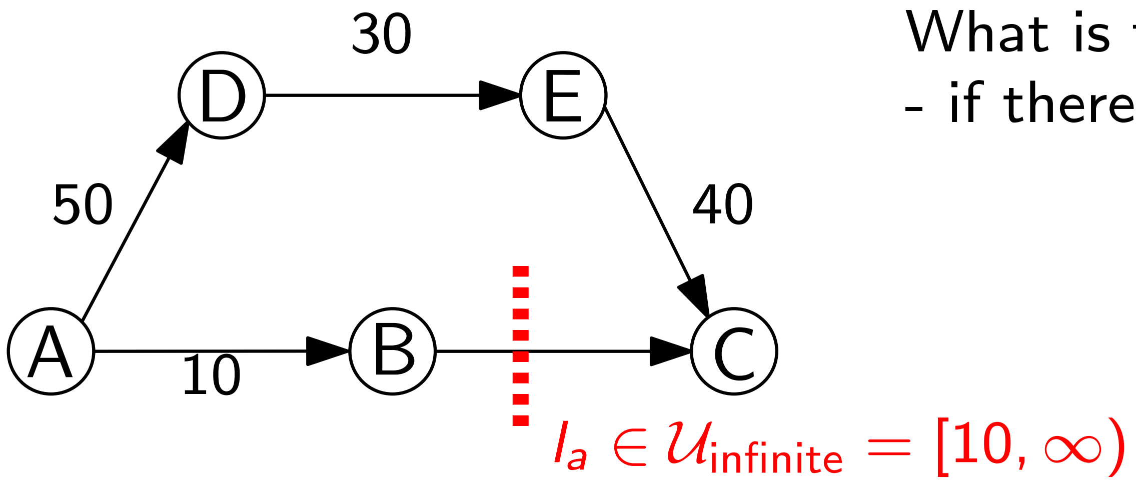

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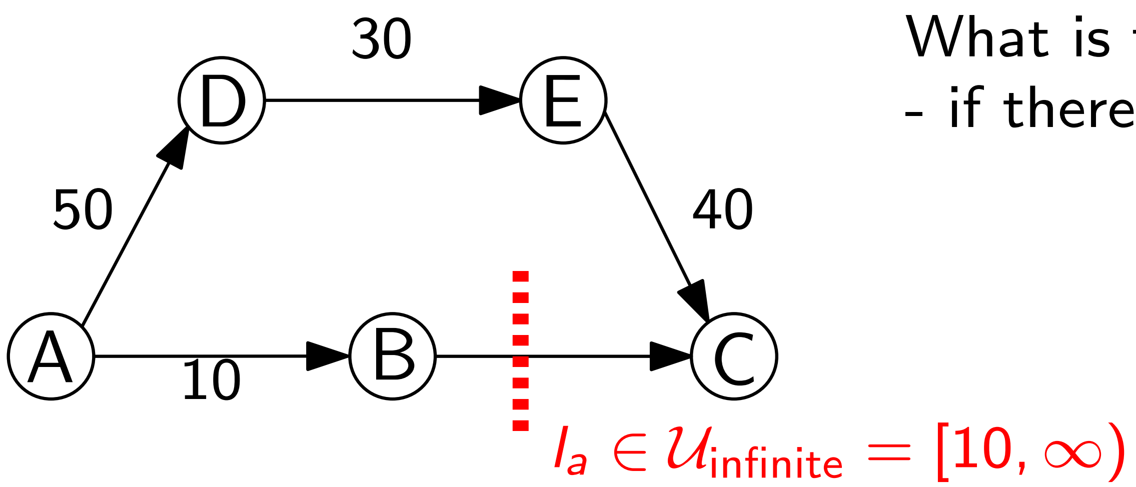

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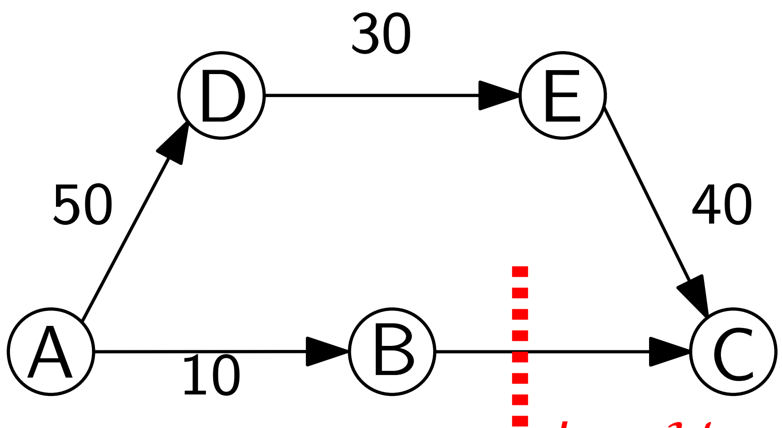

What is the best way from A to C
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$P(l_a \leq x) = 1 - e^{-0.1(l_a - 10)}$

$l_a \in \mathcal{U}_{\text{infinite}} = [10, \infty)$

What should the traveler do?

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We call the set of *scenarios* (possible travel times) *uncertainty set* $\mathcal{U}$.

$\mathcal{U}$ could be finite, bounded, or unbounded.
Possibly, we have a probability distribution on $\mathcal{U}$.

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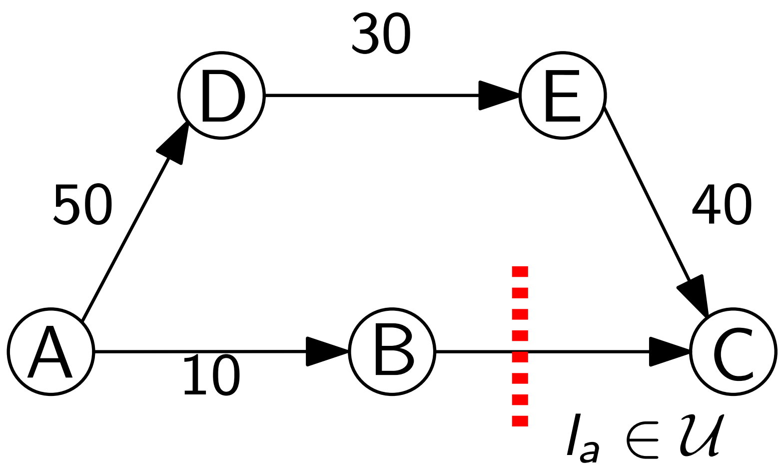

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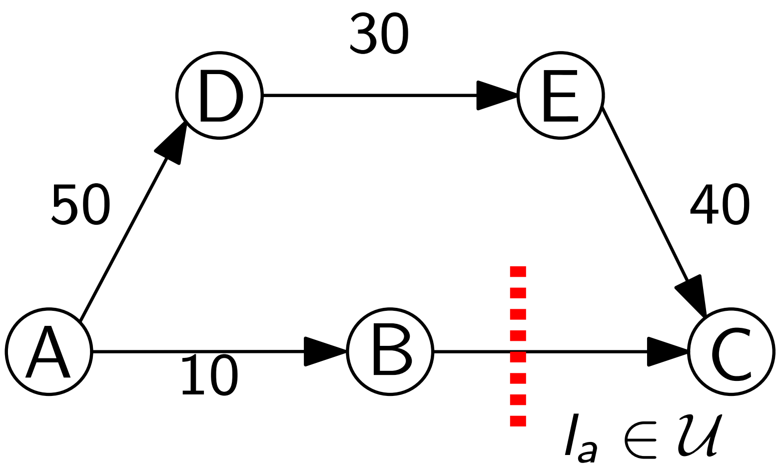

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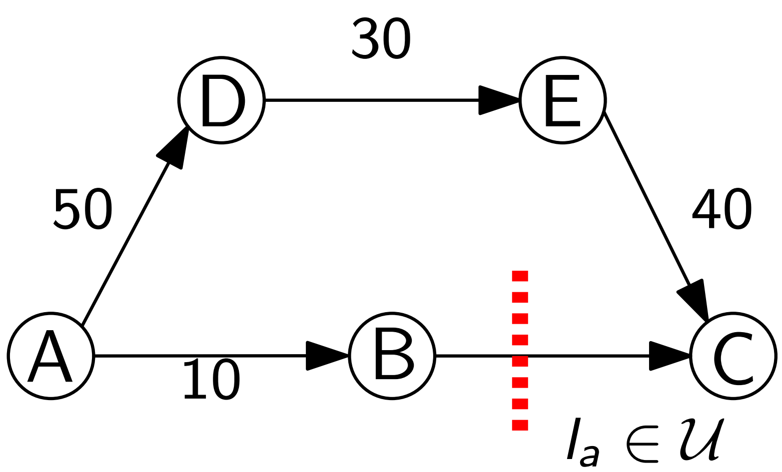

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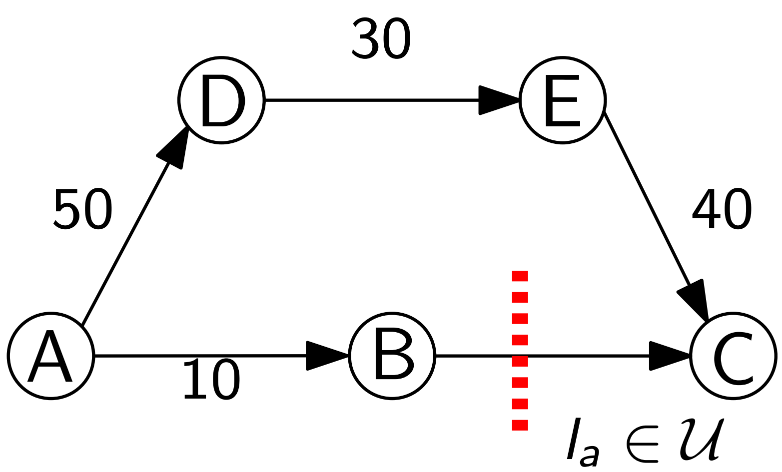

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- objective value in the worst case

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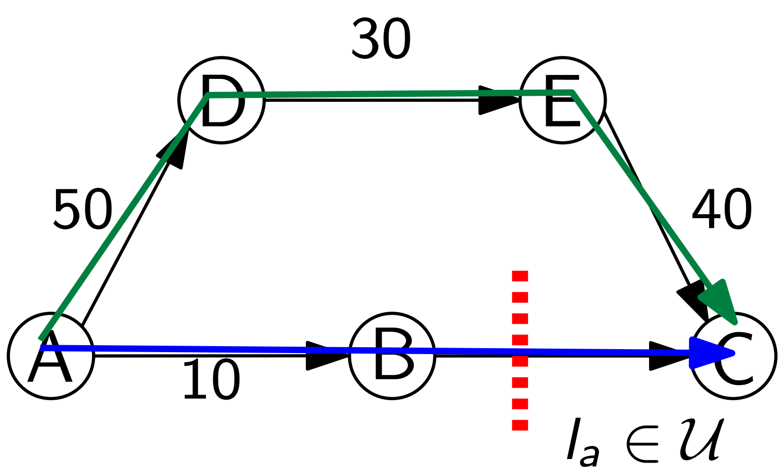

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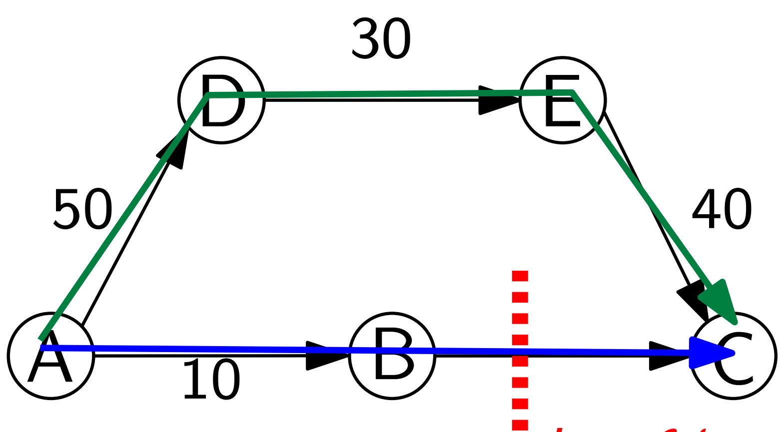

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$l_a \in \mathcal{U}_{\text{finite}} = \{10, 15, 70, 1450\}$

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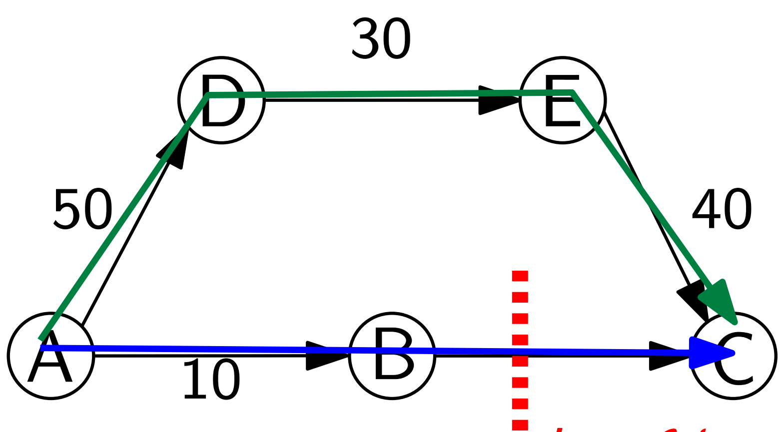

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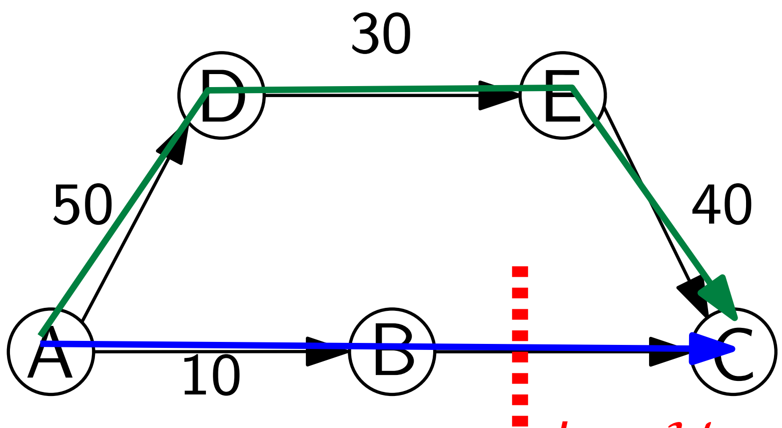
- objective value in the worst case

$z_{\text{wc}}(P_1) = 1460$, $z_{\text{wc}}(P_2) = 120$

Example: The traveler's route choice problem



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- expected objective value

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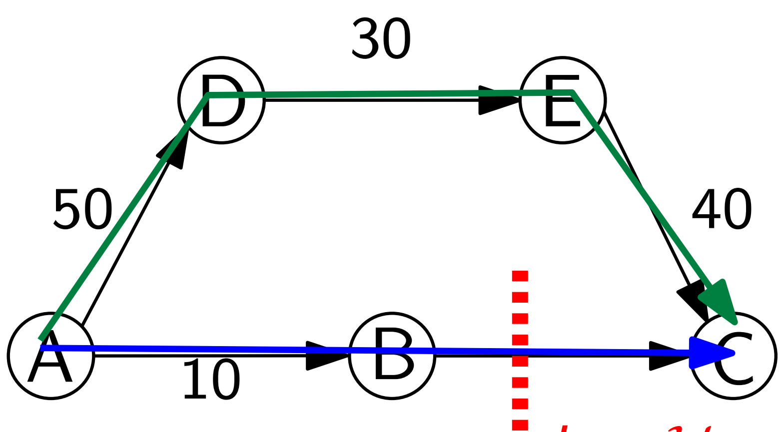

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$z_{\exp}(P_1) = 30$, $z\exp(P_2) = 120$

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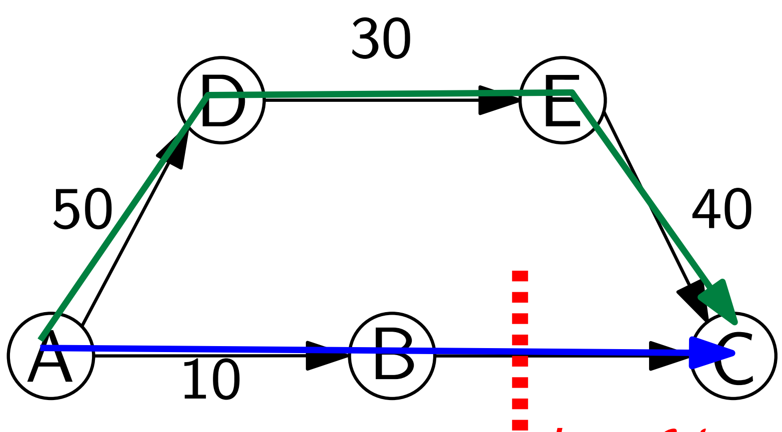

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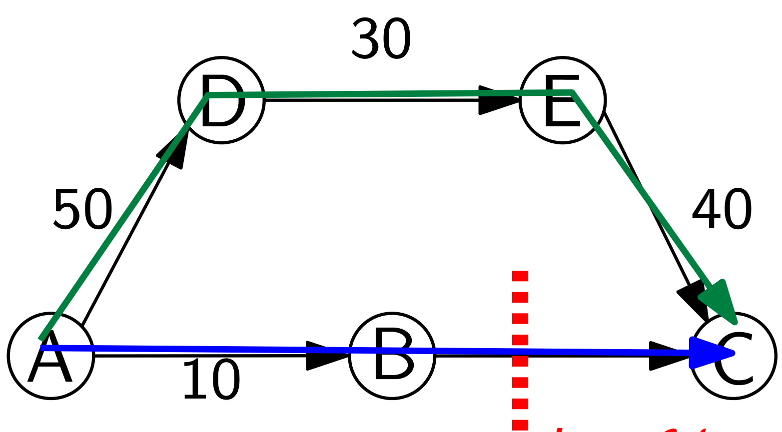
- objective value in the worst case
- expected objective value
- worst-case ratio ('competitive ratio')

Example: The traveler's route choice problem



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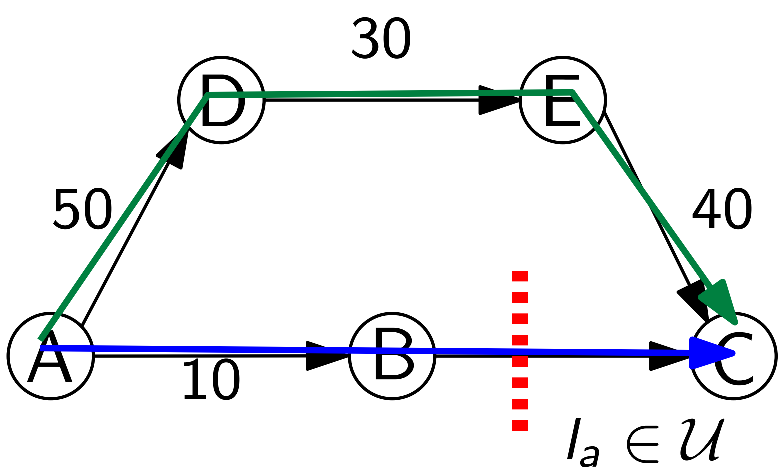
- objective value in the worst case
- expected objective value
- worst-case ratio ('competitive ratio') $z_{\text{cr}}(P_1) = \frac{1460}{120} \approx 12.08,$
  $z_{\text{cr}}(P_2) = \frac{120}{20} = 6$

Example: The traveler's route choice problem



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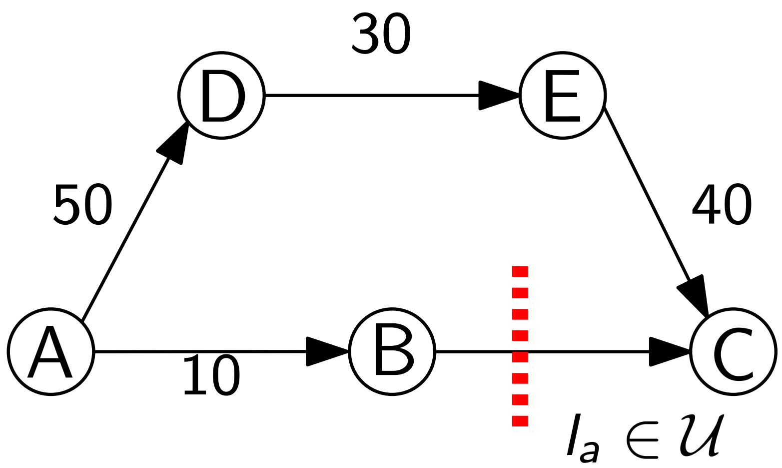
- objective value in the worst case
- expected objective value
- worst-case ratio ('competitive ratio')
- exp. ratio, worst-case/expected regret, probability to have the optimal solution, prob.to be 'on time', expected travel time in 90% of the cases, value at risk,...

Example: The traveler's route choice problem



What is the best way from A to C
- if there is a disruption on (B, C)?

What should the traveler do?

1.) gain more information on the disruption (source, estimated length etc)
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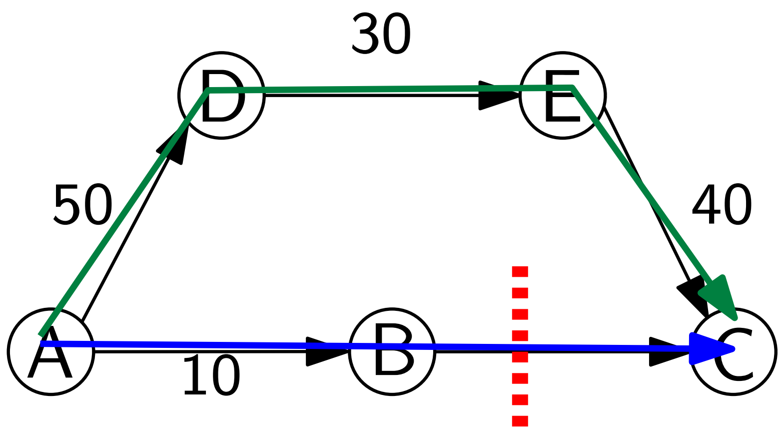

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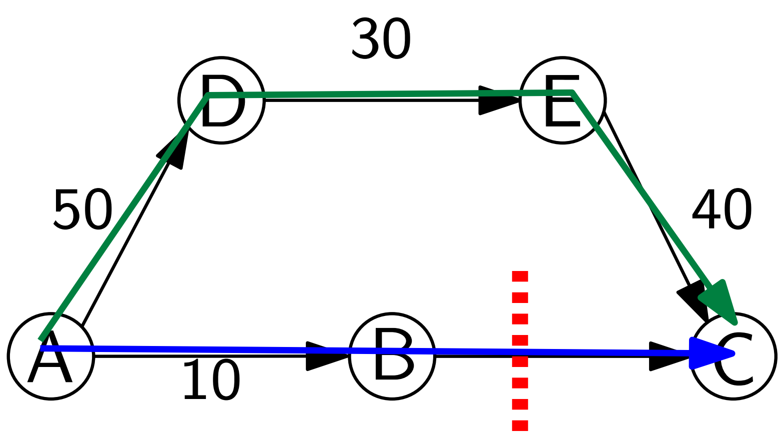

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What if the traveler can wait at A to see how the situation evolves?

Strategy *wait at A for at most 60 minutes to see if disruption has disappeared, if so, take P_1, otherwise, take P_2* has competive ratio $\frac{3}{2}$

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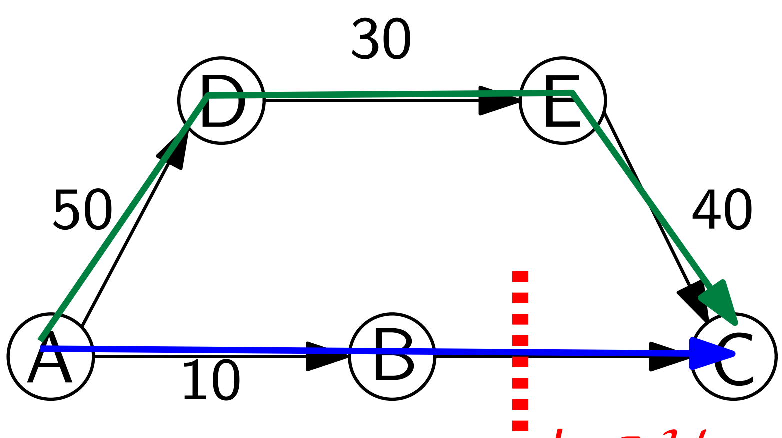

$l_a \in \mathcal{U}_{\text{finite}} = \{10, 15, 70, 1450\}$

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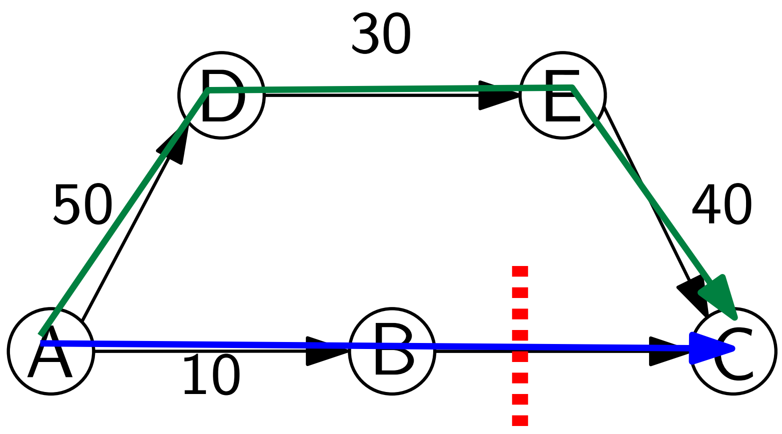

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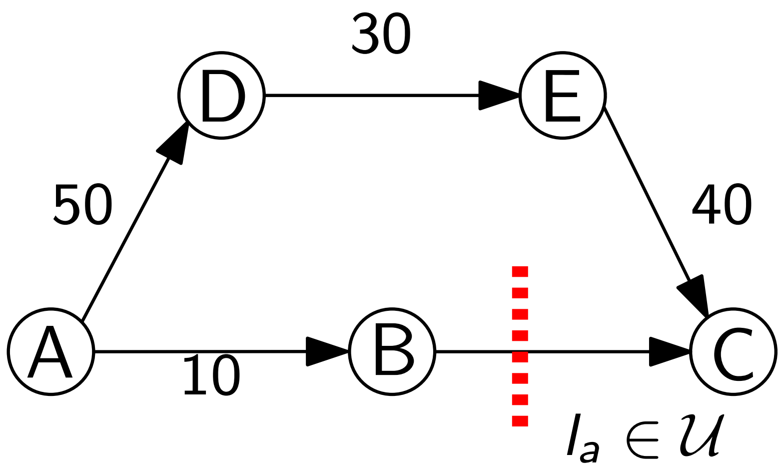

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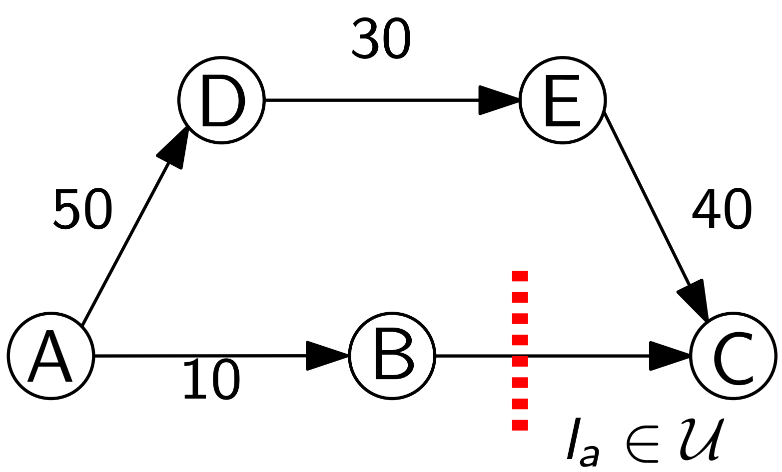

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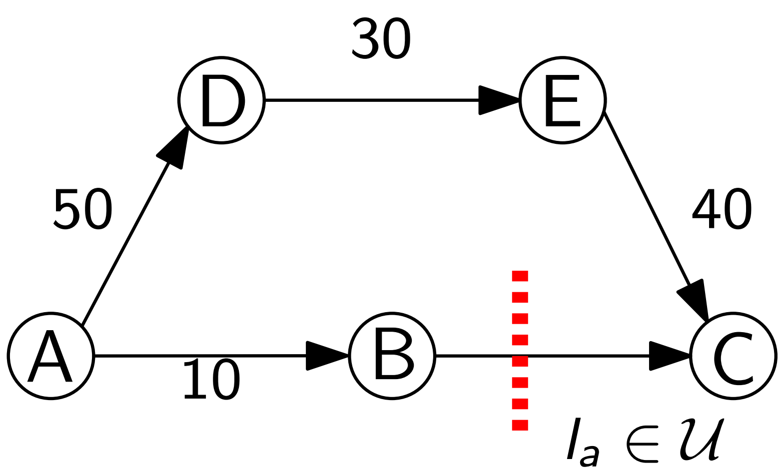

What is the best way from A to C
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What can people skilled in optimization do to help the poor traveler?

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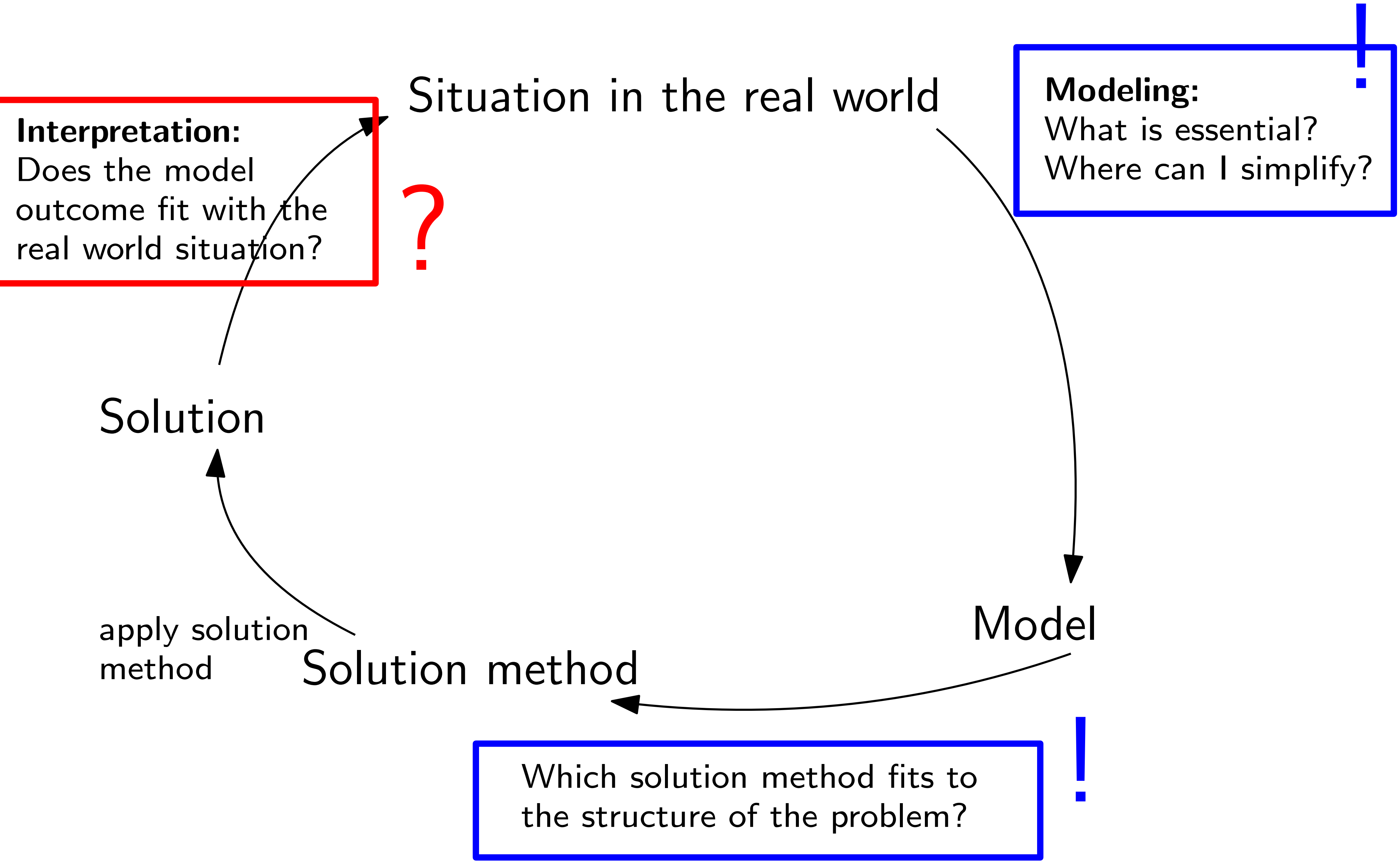
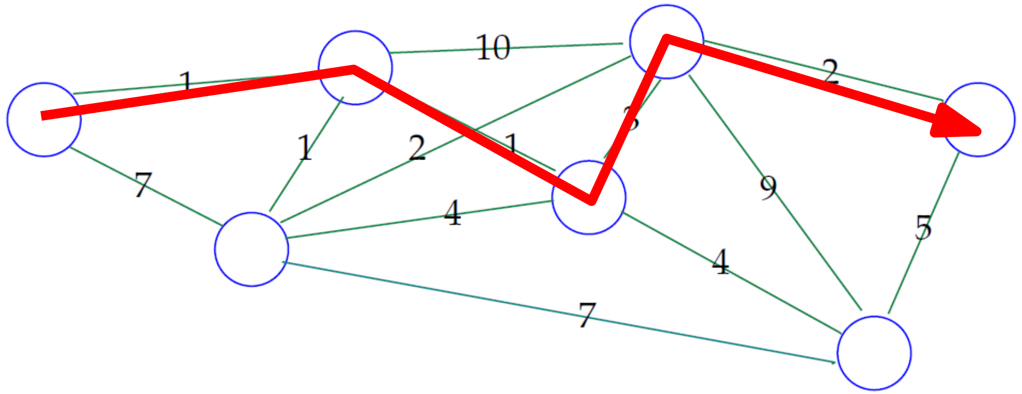
Modeling cycle for optimization problems



Problems in the focus of this seminar

- shortest path problem



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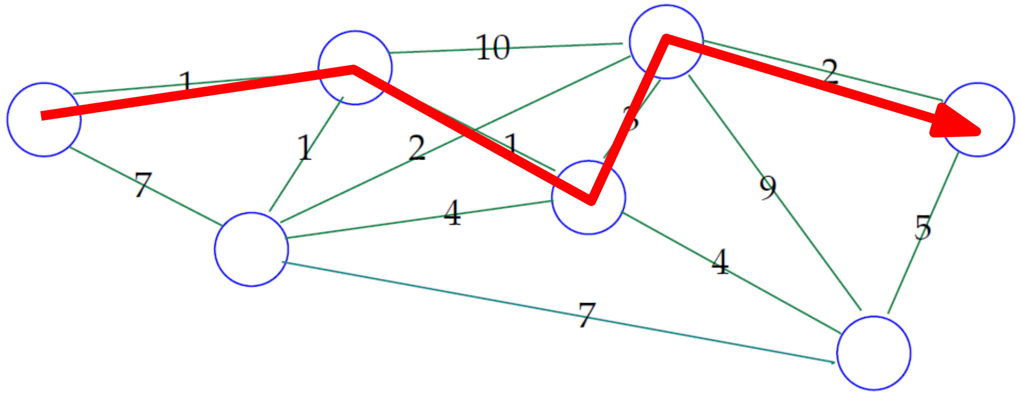
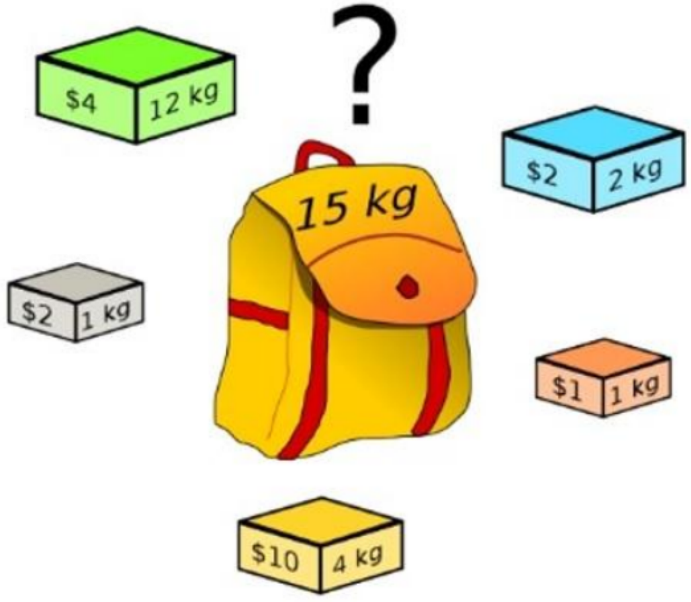


- knapsack problem



Presentation schedule

- Introduction to the shortest path problem (≈ 8.5.)

- Shortest path under uncertainty 1
- Shortest path under uncertainty 2
- ...

- Introduction to the knapsack problem (≈ 5.6.)

- Knapsack under uncertainty 1
- Knapsack under uncertainty 2
- ...

Presentation schedule

presentation dates will be assigned after this session

- Introduction to the shortest path problem ($\approx$ 8.5.)

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individual, based on a paper,(normally) 1 per session, approx. 45 minutes

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Presentation schedule

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group, 'the basics', short (*at most* 30 minutes), same day as first individual presentation of the block

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- Shortest path under uncertainty 2
- ...

- Introduction to the knapsack problem (≈ 5.6.)

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Paper selection for the individual presentations

After this session:

- consult list of papers (WueCampus)
- indicate preferences and preknowledge on WueCampus until Friday at noon
- paper assignment and schedule (including dates) will be published on WueCampus on Friday afternoon

$\leftarrow$ read/scan paper before selection!

Group presentations

All students presenting a 'shortest path' paper prepare a joint group presentation, containing

- basic information on the *deterministic* problem: definition, complexity, (illustration of) solution methods

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Tip: use (a deterministic version of) the same instance to illustrate the methods for the deterministic problem

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The same holds for the students with a 'knapsack' paper.

Students who present on a *different* problem include this part in their individual presentation.

Individual presentations: Structure

(0. Preliminaries: any concepts that are relevant for your paper, specifically, and that other may not know)

1. What is uncertain (and why)? How is the uncertainty set defined? Do we have a probability distribution?

2. What could go wrong if we just took the deterministic solution?

3. Which solutions are considered 'feasible'?

4. How are solutions *evaluated under uncertainty*?
Tip: illustrate this on the deterministic solution

5. Solution method from paper,
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(6. Own ideas - see next slide)

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If you present on a problem that is not shortest path or knapsack, this includes problem definition & methods for the deterministic case.

Individual presentations

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Activate your audience:

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You present uncertainty set, optimality concept, and (idea of) the method.

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often most suitable for activating the audience

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Report

At the end of the term, each student hands in a report consisting of the following parts:

1. basic information on the *deterministic* problem
2. example instances

3. uncertainty & uncertainty set
4. solution space (feasibility) and evaluation under uncertainty
5. solution method

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individual work

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individual or group work

Example questions on what to think about here:

- Would the method from 'my' paper also work for other uncertainty sets/evaluation functions/optimization problems? Why? Why not? Could it be modified?
- Would the method from another paper also work on my problem? Why? Why not? Could it be modified?
- How would I solve the problem if I had a different uncertainty set/evaluation function?
- ...

Grading criteria

- clear structure
- concepts and methods are clearly presented and well understood
- appropriate level of abstraction
- questions well answered
- appropriate length
- on group work component: all group members contribute
- specific to presentation: well-designed interactions, audience succesfully activated

WueCampus and WueStudy

WueCampus: Course materials (including lecture slides) and course information, forum for questions and discussions, course communication, **paper list, link for paper choice/assignment**

Please sign up.

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Please sign up.

WueStudy: here you register for the examination.
Important: register until **31.05.**2024 or we cannot book your grade!

Questions and support

Do you have any questions now?

presentation preparation:

- slides to be sent 10 days before presentation (Sunday evening) to marie.schmidt@uni-wuerzburg.de
- slide feedback meeting 7 days in advance (after seminar)

further question? meeitng timeslots bookable on doodle