XAVIER CEUGNIET,   IBM DATA AND AI

A COGNITIVE MODELING ASSISTANT
TO OPTIMIZE COMPLEX DECISIONS

A SIMPLE SCHEDULING DEMO

AN APPROACH TO COGNITIVE MODELING

LEVERAGING YOUR OWN DOMAIN KNOWLEDGE

A SIMPLE SCHEDULING DEMO

THE COGNITIVE OPTIMIZATION FRAMEWORK

LEVERAGING YOUR OWN DOMAIN KNOWLEDGE

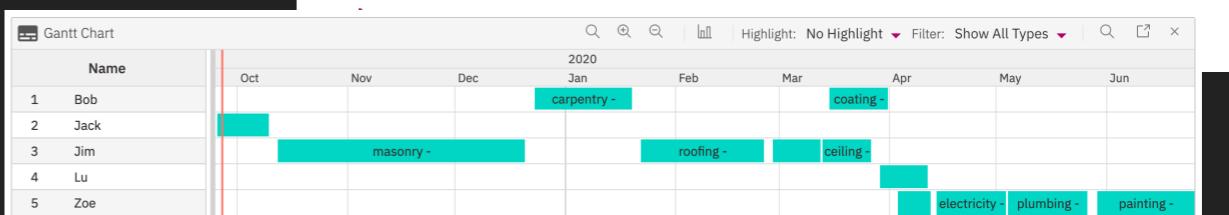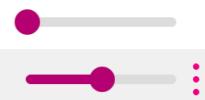Schedule and assign Work to Subcontractors ✎

Objectives

> Minimize time to complete all Work

> Minimize overall cost of Subcontractor to Work assignments according to Estimates

Constraints

Each Subcontractor can only be used on 1 task at a time

The number of Subcontractor assignments for each Work is equal to 1
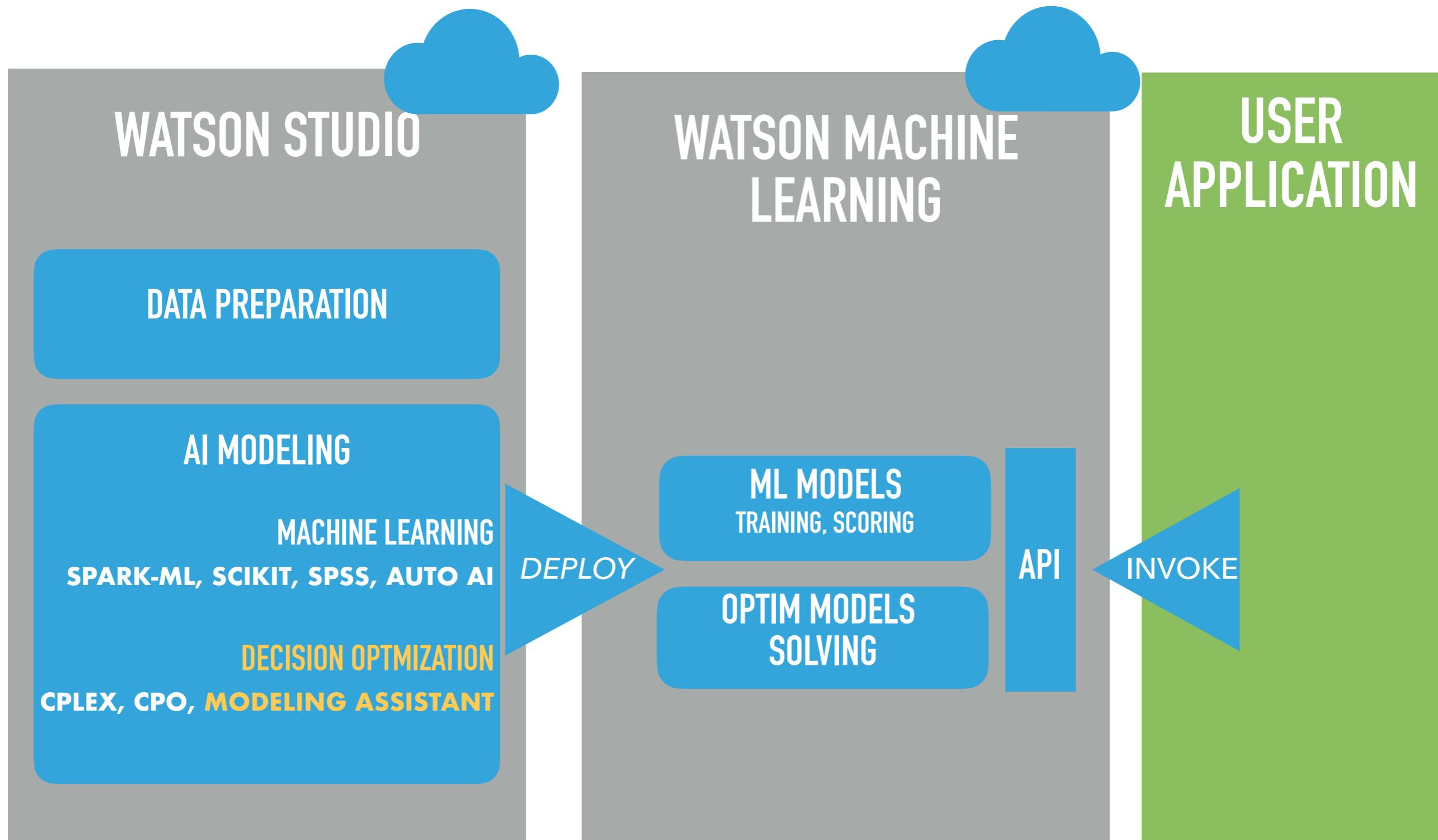
All Work are scheduled

> The schedule must respect the duration specified for each Work

Schedule start is 2019/09/25 00:00:00

Each Work starts after the end of Preceding works with a delay min of 2 days

Gantt Chart — Highlight: No Highlight — Filter: Show All Types

	Name	2020								
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1	Bob				carpentry -		coating -			
2	Jack									
3	Jim		masonry -		roofing -	ceiling -				
4	Lu									
5	Zoe							electricity -	plumbing -	painting -

A SIMPLE SCHEDULING DEMO

AN APPROACH TO COGNITIVE MODELING

LEVERAGING YOUR OWN DOMAIN KNOWLEDGE

LOCATED IN A MACHINE LEARNING & OPTIM. CLOUD

WATSON STUDIO

DATA PREPARATION

AI MODELING

MACHINE LEARNING

SPARK-ML, SCIKIT, SPSS, AUTO AI

DECISION OPTMIZATION

CPLEX, CPO, MODELING ASSISTANT

DEPLOY

WATSON MACHINE LEARNING

ML MODELS
TRAINING, SCORING

OPTIM MODELS SOLVING

API

INVOKE

USER APPLICATION

CAPTURING & SOLVING A DECISION MODEL

Decision Model : A set of business concepts, decision types and decision rules

- ▸ Formalizing a decision problem

- ▸ Verbalized in natural language

- ▸ Can be translated to an optimization model

DECISION OPTIMIZATION
MODELING ASSISTANT

DECISION MODEL ELICITATION

OPTIM MODEL GENERATION

SOLUTION / CONFLICT REPORTING

SOLVING
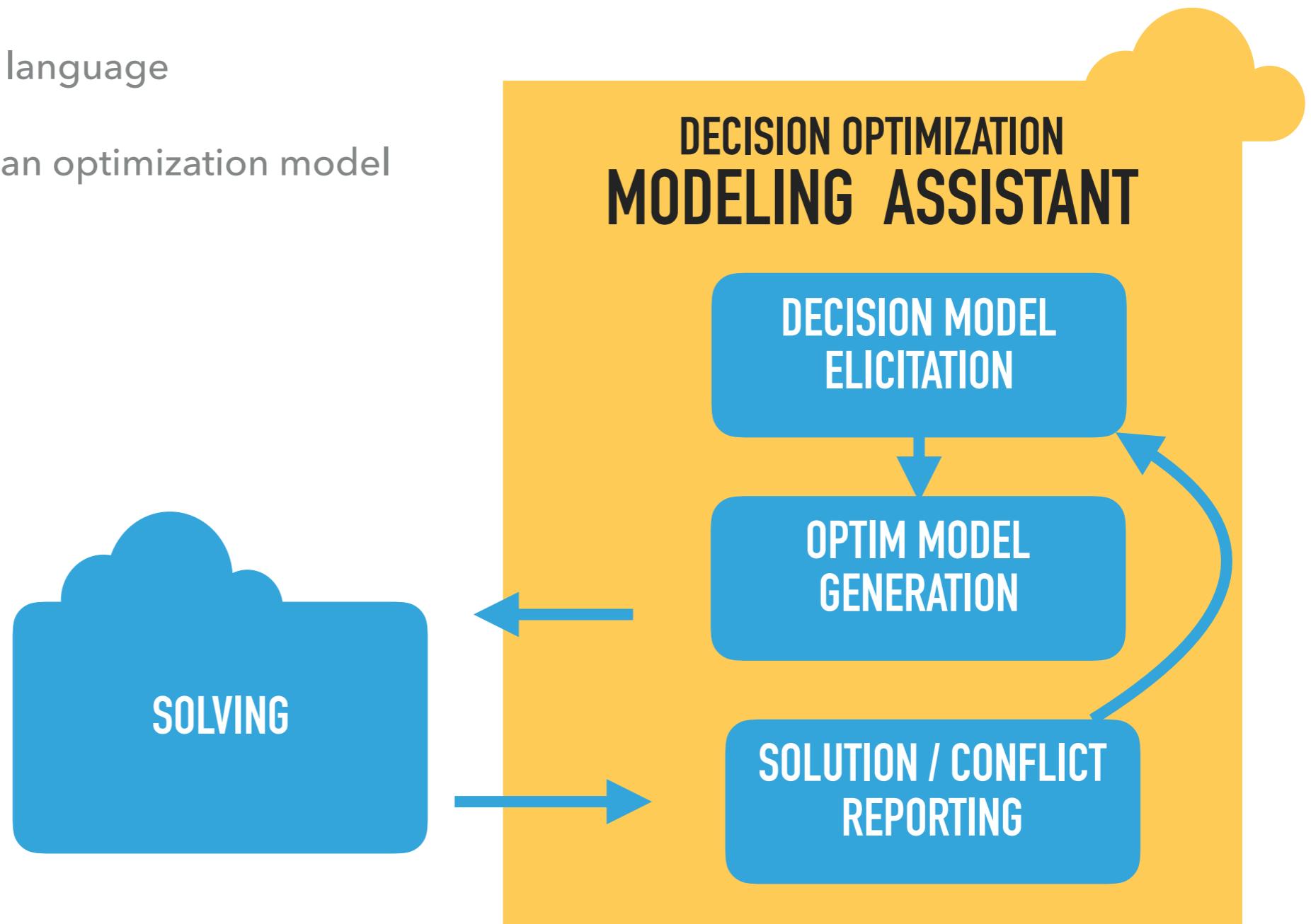
DECISION MODEL ELICITATION STEPS
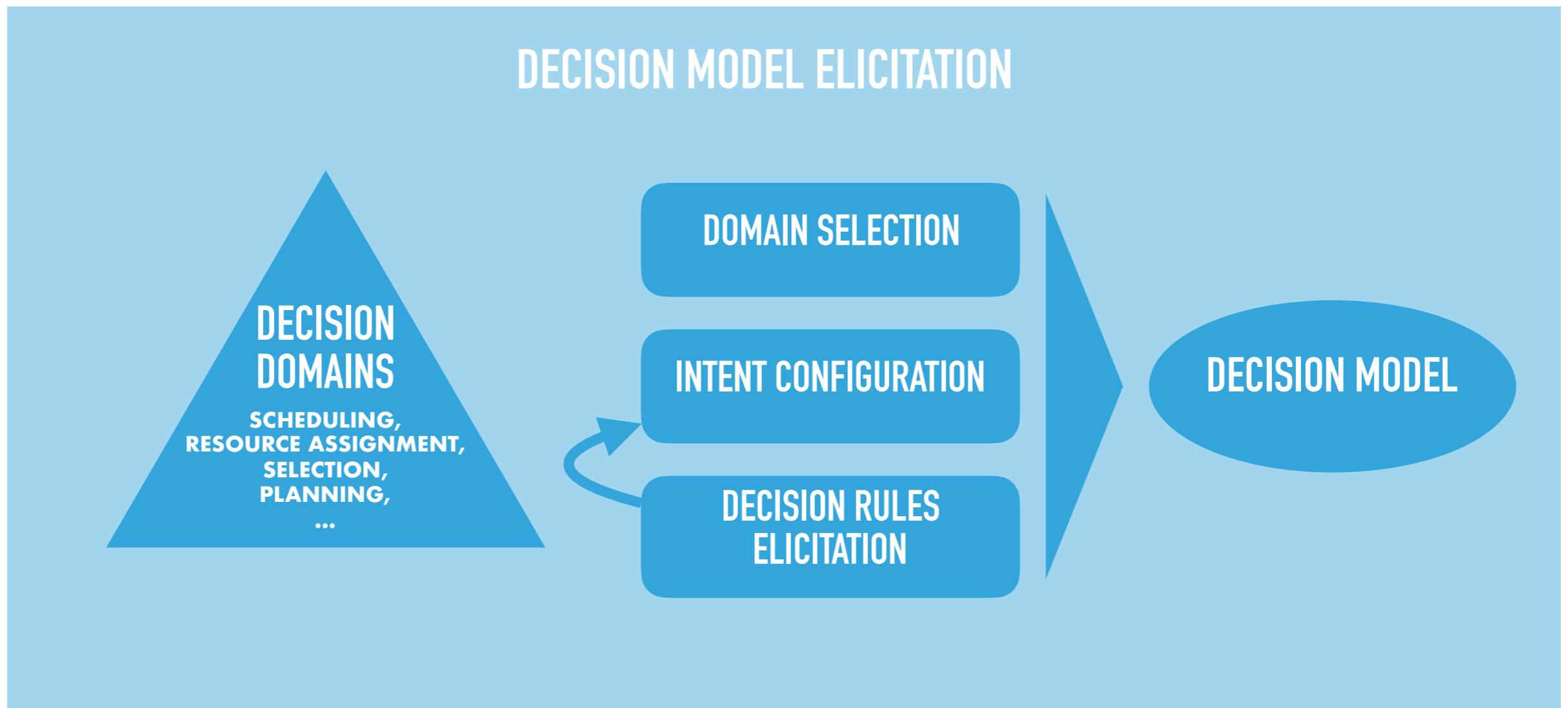
DECISION DOMAINS

Define a class of decision problems characterised by :

DOMAIN CONCEPTS Typical entities/elements entering the problem definition

e.g. Task, Resource, Distance matrix

INTENT TEMPLATES Typical problems than can be addressed

e.g. Schedule <tasks> and allocate <resources>

DECISIONS TYPES Possible decisions to be taken

e.g Task start/end date, Resource-Task allocation

**DECISION RULES TEMPLATES** Pattern of business constraints, business goals, business kpis

e.g Schedule must comply with <duration> of <task>

e.g Maximize overall value of <assignments> w.r.t. <value table>

DECISION DOMAIN LIBRARY

Decision domains are organised in an open hierarchy, where more specialised domains inherits the elements - domain concepts, decisions, intents & rules templates - defined in ancestors
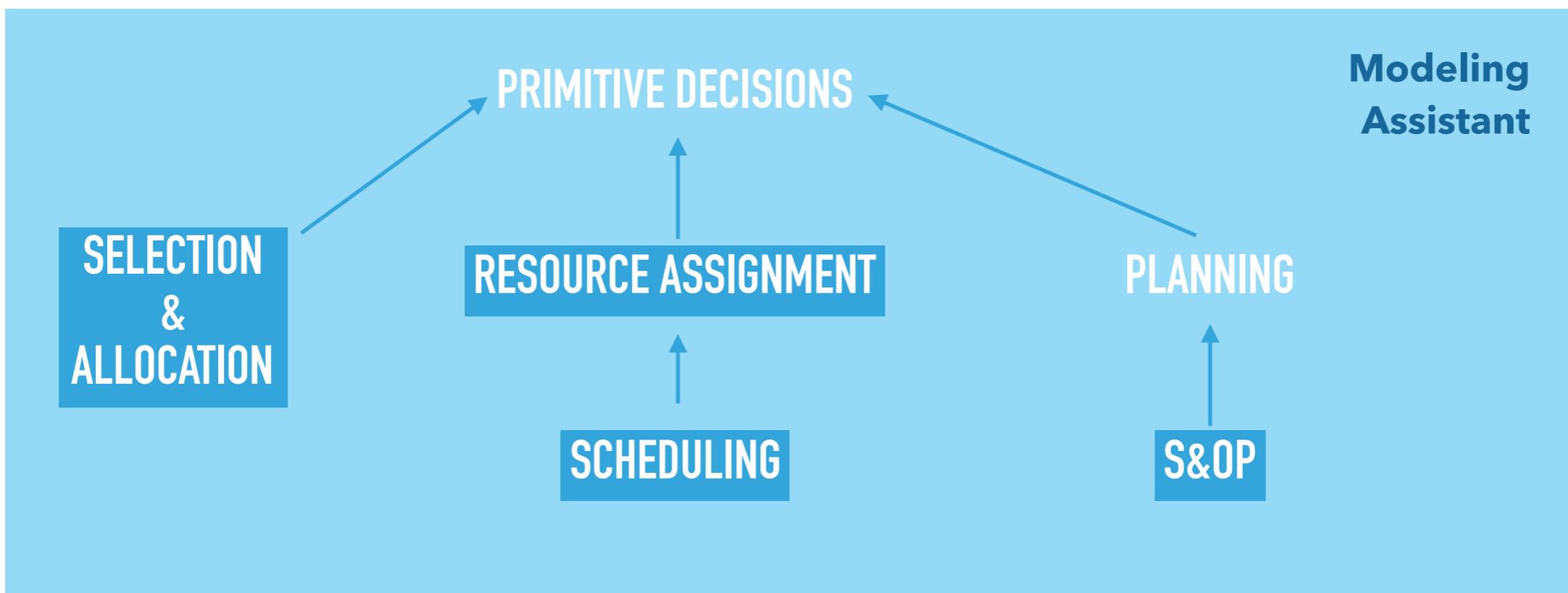
INTENT CONFIGURATION

To map the main business concepts to user data and to identify main decisions

What are the tasks and resources for scheduling?

TASKS ⓘ

Pick at least one data table or column that describes the tasks.

| Activity ✕ | Another task ? ⌄ |

RESOURCES (Optional) ⓘ

Pick data that describes the resources to be used by the tasks.

| Choose a resource ⌃ |

- Estimate
- Precedence
- Subcontractor

Based on what you have defined, here is your problem formulation.

Schedule and assign Activities to Subcontractors.

Decision model initialisation

Definition of vocabulary

- Activity is a Task
- Subcontractor is a Resource

Definition of main decision types

- Activity duration, start , end
- Subcontractor-Activity assignment

DECISION RULES ELICITATION

Elicitation relies on **Suggestions** computed by Modelling Assistant, based on:

- rule templates with verbalisation & clues

- user data, decisions,

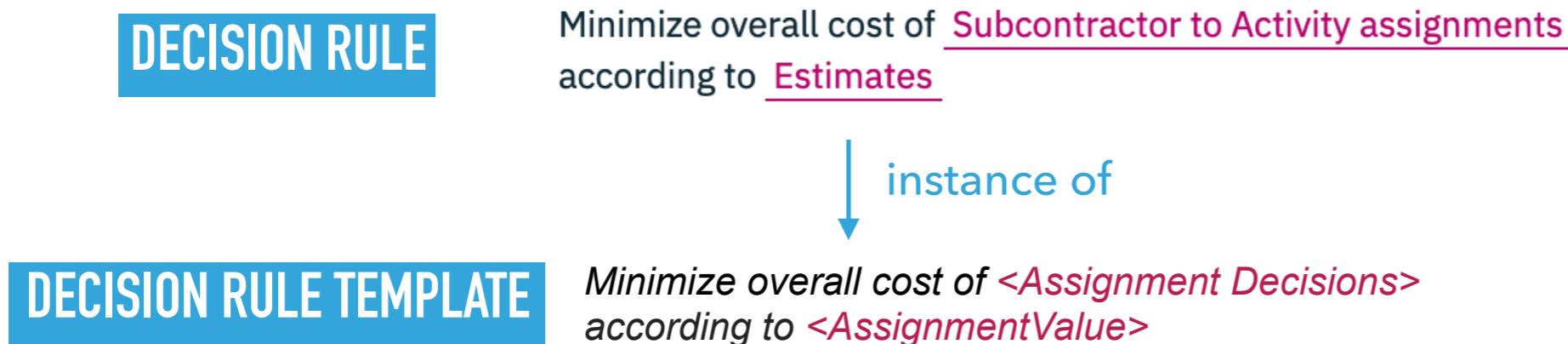- rules already elicited, vocabulary definitions

- optional user query, e.g :

USER QUERY

activity after preceding with 2 days delay   ✕ 🔍

SUGGESTIONS

⊕ Each Activity starts after the end of Preceding activities with a delay max of 2 days

⊕ Each Activity starts after the end of Preceding activities with a delay min of 2 days

⊕ Each Activity starts after the end of Preceding activities with a delay between 2 days and a maximum delay

INFERRING VOCABULARY DEFINITION

An elicited rule may require additional vocabulary definitions on user data to be fully defined

STEP 1 : The user selects a suggested rule (an instance of a rule template)

DECISION RULE   Minimize overall cost of Subcontractor to Activity assignments
according to Estimates

instance of

DECISION RULE TEMPLATE   *Minimize overall cost of <Assignment Decisions>
according to <AssignmentValue>*

STEP 2: The Modeling Assistant deduces some definition from the rule

USER DATA   Estimate

is a

DOMAIN CONCEPT   AssignmentValue

DECISION RULES ELICITATION

STEP 3: The modeling assistant identifies vocabulary definitions required by the rule

> Minimize overall cost of Subcontractor to Work assignments
> according to Estimates
> The resource of Estimate is defined by Subcontractor
> The task of Estimate is defined by Work
> The value of Estimate is must be defined

STEP 4: The definitions need to be completed before a solve can be executed

DOMAIN CONCEPT

```
AssignmentValue
      property task as Task
      property resource as UnaryResource
      property value as Numeric
```
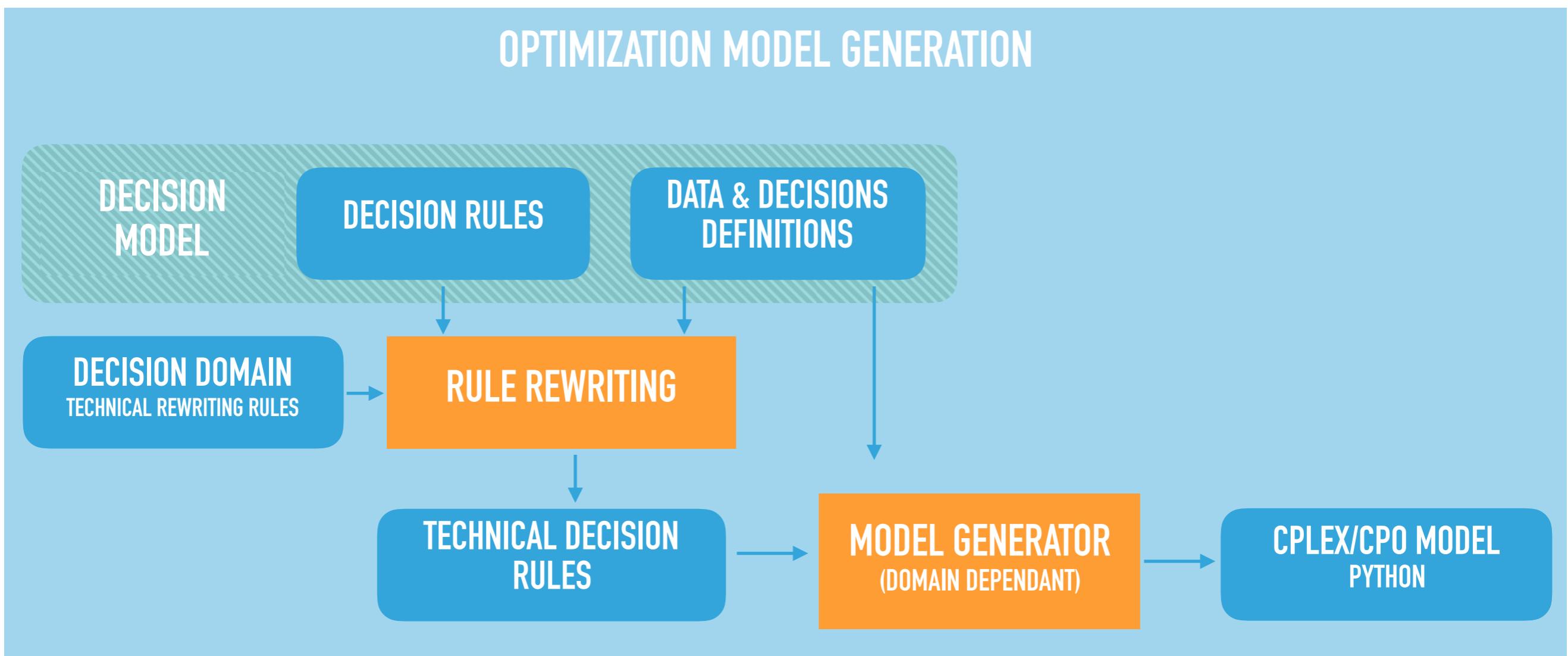
USER DATA

Estimate

	Activity	Subcontractor	K$ Estimate
	String	String	Number
1	earthwork	Jim	17

REQUIRED DEFINITIONS

The task of Estimate is defined by Activity

The resource of Estimate is defined by Subcontractor

The value of Estimate is defined by K$ Estimate

OPTIMIZATION MODEL GENERATION

When a solve is requested, the decision model is first translated to an optimization model.

OPTIMIZATION MODEL GENERATION

DECISION MODEL

DECISION RULES

DATA & DECISIONS DEFINITIONS

DECISION DOMAIN
TECHNICAL REWRITING RULES

RULE REWRITING

TECHNICAL DECISION RULES

MODEL GENERATOR
(DOMAIN DEPENDANT)

CPLEX/CPO MODEL
PYTHON

Rule rewriting allows to reduce complexity of the model generator associated to a domain

GENERATED OPTIMIZATION MODEL

‣ Model generated in Python, using Pandas for data & solution processing

‣ The model can be exported as an Notebook in Watson Studio and extended by an OR expert
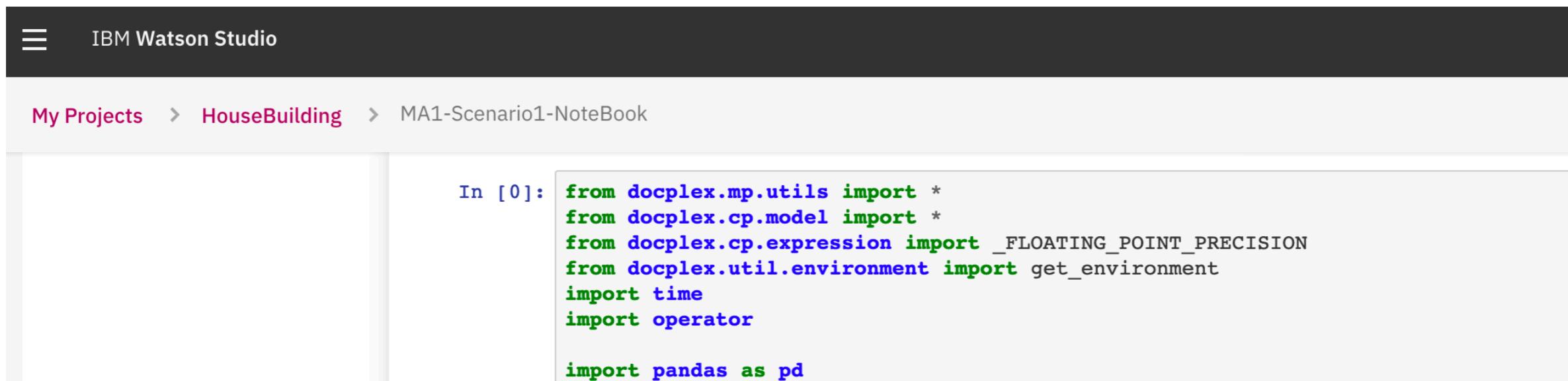
Modeling assistant can be used as a starting point for advanced optim. model

A SIMPLE SCHEDULING DEMO
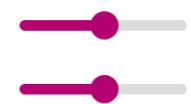
INSIDE COGNITIVE MODELING

LEVERAGING YOUR OWN DOMAIN KNOWLEDGE

Modeling Assistant **Replace**

Decide the production of Units to cover the demand on each Period ✎

Objectives

> Minimize total costs of production of Units by Periods
> Minimize overall noxious emissions w.r.t table of Energy

Constraints

> Respect the maximum production capacity of each Unit
> The production of Units by Periods should cover forecasted demand as defined in Demand
> Global settings as first period or last period, are defined in table UC_Settings
> Respect ramp-up capacity of each Unit
> Take into account forecasted production of specific units given by table SolarEolians

… WITH A CUSTOM DECISION DOMAIN

▸ In case you are an expert of solving a type of industry-specific decision problem

▸ 'Just write' and import a custom domain in Modeling Assistant

▸ Allowing your decision makers or consultants with no OR skills to deliver optimization models

▸ E.g. Unit Commitment domain

Decide the production of Units to cover the demand on each Period

Objectives

> Minimize total costs of
  production of Units by Periods

> Minimize overall noxious emissions w.r.t table of
  Energy

Constraints

> Take into account forecasted production of specific units given by
  table SolarEolians

> Respect ramp-up capacity of each Unit

… WITH A CUSTOM DECISION DOMAIN

▸ Custom domains make formulation of rules much more intuitive

THE BUSINESS CONSTRAINT

A production unit cannot be at 100% capacity at once.

Ramp-up capacity of unit should be taken into account

….WITH RESOURCE ASSIGNMENT

For each UnitPeriod , total Unit to Period allocations where allocated Unit is unit and
where allocated Period is next of period   is less than or equal to
ramp_up of unit + total Unit to Period allocations where
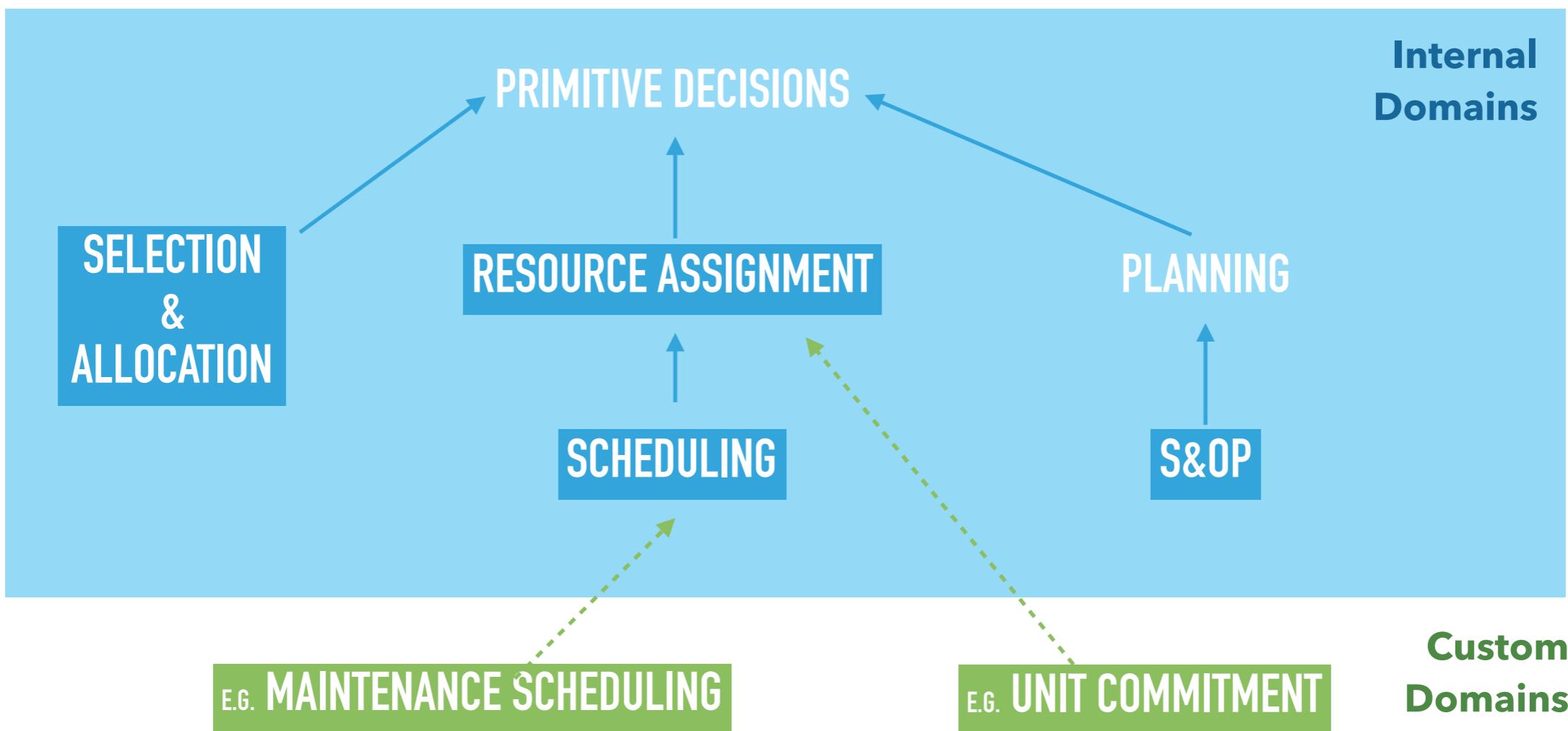Unit to Period allocation is joined to UnitPeriod

….WITH UNIT COMMITMENT

+ similar one for first period…

⌄ Respect ramp-up capacity of each Unit
    The nextPeriod of Period is defined by next
    The firstPeriod of UC_Settings is defined by firstPeriod
    The lastPeriod of UC_Settings is defined by lastPeriod
    The initialProd of Unit is defined by initial_prod
    The rampUp of Unit is defined by ramp_up

EXTENDING DECISION DOMAIN LIBRARY

By inheriting elements from an internal domain, a custom domain writer can focus on adding domain specific business concepts , decision types, rule templates (intents, goals, constraints, kpis)

Internal Domains

PRIMITIVE DECISIONS

SELECTION & ALLOCATION

RESOURCE ASSIGNMENT

PLANNING

SCHEDULING

S&OP

E.G. MAINTENANCE SCHEDULING

E.G. UNIT COMMITMENT

Custom Domains

Writing optimization generation code is only required for rules that cannot be rewritten as rules of parent domain

FUTURE WORK

Improve suggestions

by better NL query processing

by learning about solutions

Improve smart visualisation

Visualisation is key for business experts to evaluate quality of a model

Improve industry covering

Build a community of decision domain contributors

THANKS !

Q&A

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