Comments on the specs03.pdf, version of Sep. 15

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SEPTEMBER 17, 2021

Note: This draft contains a still incomplete SMS.

Editorial

Please ALWAYS place on ANY document: your name, the current date, page numbers, and line numbers.

1 Symbolic model specification (SMS)

The SMS documents all model entities (indexing structure, variables, parameters, relations). This draft is an incomplete SMS aimed at illustrating the SMS structure and basic elements.

1.1 The model purpose

The model aims at supporting analysis of the relations between the decisions on the use-level of the technologies for producing liquid fuels, and the consequences of implementation of such decisions. The consequences are measured by values of the outcome variables.

1.2 Indexing structure

1.2.1 Intro to indexing structure

The SMS uses the Structured Modeling (SM) concepts; in particular the compound entities. For example, a compound variable $\mathbf{x}$ actually represents a set of variables $x_{ij}, i \in I,\ j \in J$, where i and j stand for indices, and I and J are the sets of values of the corresponding indices. To illustrate this concept, let $\mathbf{x}$ be flows between i-th warehouse and j-th store. Then the set I of warehouses can be defined as $I = \{city1, city2, \dots\}$. Similarly, the set J of shops can be defined as $J = \{loc1, loc2, \dots\}$.

Thus, the indexing structure is composed of:

- symbols of indices (typically a lower-case letter), and
- symbols of sets (typically, the corresponding upper-case letter).

The examples of the index-sets below are for illustration only. The actual members of these sets are defined by the model parameters.

1.2.2 Indexing structure of the model

The model uses the following indices and the corresponding sets:

- $t \in T$ technologies: $T = \{\mathrm{OTL}, \mathrm{BTL}, \mathrm{PTL}, \dots\}$, $T_f \subset T$ technologies directly producing the final commodities

- $p \in P$: the ids of the 5-year planing periods. Instead of using the calendar-year values, we use sequence of positive integer values, i.e., for the calendar years {2020, 2025, ..., 2050} we index the planning periods by $P = \{1, 2, \ldots, 7\}$. The correspondence between the planning periods and the calendar years can be defined (for reporting) by a simple mapping.
- $v \in V$: vintage (period in which the capacity becomes available) period id. The duration (consecutive periods during which the capacity remains available) of each newly installed capacity is defined by the parameter τ; e.g, $\tau = 4$ defines the duration of the capacity equal to 4 periods, i.e., 20 years. Therefore, $V = H \cup P$ where H is the set of historical (prior to the first planning period) periods in which the installed capacities can still be used during the planning periods. Thus, for τ equal to 4, $H = \{-2, -1, 0\}$, i.e., the capacities installed in any of the three periods before the first planning period are available to be used in the first planning period.
- $c \in C$: commodity. E.g., $C = \{\text{oil}, \text{gasoline}, \text{coal}, \text{crude} - \text{oil}, \ldots\}$. Commodities belong to diverse subsets that correspond to their roles:
  - ⋄ $C_f \subset C$: final commodities (currently: gasoline and diesel-oil),
  - ⋄ $C_i \subset C$: commodities required as inputs for activities of technologies $t \in T$,
  - ⋄ ... (more subsets shall be defined).
- ... (more indices may be needed).

Notes for Jinyang:

- I strongly recommend to refrain from using v^y (or any other symbol defined by a letter with subscript/superscript) for an index. Therefore, I propose to use v for the vintage period index.
- We don't need in the SMS: $y \in Y$ 5-year period id, $Y = \{2020, 2025, \ldots 2050\}$.

1.3 Variables

Although all variables are treated equally within the model, we divide the set of all model variables into categories corresponding to the roles; this helps for structuring the model presentation.

1.3.1 Decision variables

Decision-makers control the modeled system by decision (control) variables:

- $cap_{tv}, t \in T, v \in P$: new production capacity of t-th technology, made available at the beginning of v-th period,[1]
- $act_{tvp}, t \in T, v \in V, p \in P$: activity level of t-th technology, using in period p the new capacity provided in period v.

Editorial notes:

- We use[2] a short notation, i.e., x_{ijk} instead of $x_{i,j,k}$.
- Further on, we skip the obvious explanations of the meaning of the indices.

[1] I don't think we need "new" capacities, because capacities are indexed by v, which means that each capacity was "new" in v-th period, and remains available in this period as well as in $\tau - 1$ following periods.

[2] JZ: it is up to you, which of these two notations you want to use. For the compactness I usually use the short one.

1.3.2 Outcome variables

Outcome variables are used for evaluation of the consequences of implementation of the decisions; therefore, at least one of them is used as the optimization objective.

In the model prototype only two outcomes (both used as criteria in multiple-criteria model analysis) are defined:
• $cost$: the total cost of the system over the planning period, and
• $CO2$: the total CO2 emission caused by the production system.

1.3.3 State variables

The variables defining the state of the system:
• ... (to be defined, if needed).

1.3.4 Auxiliary variables

All other variables used in the SMS:
• $actInp_{cp}$ input resources required by all technologies $t \in T$
• ... (all remaining variables, to be defined).

1.4 Parameters

The following model parameters are used in the model relations specified in in Section 1.5:
• values of indices (members of sets) specified in Section 1.2.2,
• τ: lifetime (number of periods) of the new capacity (equal for all technologies),
• $d_{cp}, c \in C_f$: demand for final commodities defined by $C_f \subset C$
• a_{tvc}: amount of output from the unit of the corresponding activity
• inp_{ctv}: amount of input required by the unit of the corresponding activity
• ef_{tv}: CO2 emission factor
• $invC_{tv}$: unit investment cost of new capacity
• $omcC_{tv}$: unit OMC of activity
• $extP_{cp}$: unit price of external input resources
• $utlF_t$: capacity utilization factor
• ... (the list is incomplete)

1.5 Relations

The values of the model variables conform to the following model relations.
• The sum of activities act_{tvp} shall result in producing the required amounts of the final commodities:

$$\sum_{t \in T_f} \sum_{v \in V_p} a_{tvc} \cdot act_{tvp} \geq d_{cp} \quad c \in C_f, p \in P. \tag{1}$$

where $V_p \subset V$ is defined by:

$$V_p = \{p - \tau + 1, p - \tau + 2, \ldots, p\}. \tag{2}$$

The parameter $\tau > 1$ defines the number of following periods during which the capacity installed in v-th period remains available for the corresponding activity. In the prototype implementation, the value of τ is equal for all technologies.[3]

- The levels of activities cannot exceed the corresponding available capacities:

$$act_{tvp} \leq utlF_t \cdot cap_{tv}, \quad t \in T, v \in V_p, p \in P. \tag{3}$$

Note: The values new capacities cap_{tv} within the planning period ($v \in P$) are defined by the decision variables. However, for the non-positive values of V_p (i.e., historical investments) the cap_{tv} values are defined by the model parameters.

- Each activity requires the corresponding input resources. The following relation defines the inputs of the corresponding commodities required as inputs by all technologies:

$$actInp_{cp} = \sum_{t \in T} \sum_{v \in V_p} inp_{ctv} \cdot act_{tvp}, \quad c \in C_i, \ p \in P \tag{4}$$

- Note: relations describing the up-stream technologies need to be added here
- The total CO2 emission caused by the activities is defined by:

$$CO2 = \sum_{p \in P} \sum_{t \in T} \sum_{v \in V_p} ef_{tv} \cdot act_{tvp} \tag{5}$$

Note: emissions from up-stream activities shall be added after these will be defined.

- Investment costs are defined by:

$$invCost = \sum_{t \in T} \sum_{v \in P} invC_{tv} \cdot cap_{tv} \tag{6}$$

- Operations and maintenance costs are defined by:

$$omc = \sum_{t \in T} \sum_{p \in P} \sum_{v \in V_p} omcC_{tv} \cdot act_{tvp} \tag{7}$$

- Costs of externally provided inputs are defined by:

$$extCost = \sum_{c \in C_i} \sum_{p \in P} extP_{cp} \cdot actInp_{cp} \tag{8}$$

- Total cost is defined by:

$$cost = invCost + omc + extCost \tag{9}$$

[3] Note that for $\tau = 4$ (the capacity life-time of 20 years) the V_p defined by (2) is equal to $V_p = \{p-3, p-2, p-1, p\}$.

Copy of comments of Sep. 1, 2021

In order to assure consistency between the problem formulation and the corresponding model, I would consider replacement of the obviously incorrect inequality (9) by:

1. Equation defining the amounts of each of the fuels as a function of the activities of the applied technologies:

$$\sum_{i \in I} a_{ji} \cdot ACT_i^t = x_j^t, \quad j \in J,\ t \in T \tag{10}$$

   where:
   - j denotes fuel type, $J = \{gasoline, diesel\}$,
   - a_{ji} relates the amount of j-th fuel produced by the unit of i-th ACT,
   - x_j^t stands for the amount of j-th fuel produced jointly by all considered technologies at period t.

2. Adding the supply-demand constraint, specification of which depends on the chosen definition of demand. Here we can consider one of the following two options:
   1. If the demand is given for each fuel type, i.e., as d_j^t, then:

$$x_j^t \geq d_j^t, \quad j \in J,\ t \in T. \tag{11}$$

   2. If the demand is given for a linear aggregation of d_j^t, e.g., by coefficients α_j conforming to:

$$0 \leq \alpha_j \leq 1,\ \forall j \in J; \quad \sum_{j \in J} \alpha_j = 1. \tag{12}$$

      Thus, the demand is given for a *virtual* (i.e., not actually existing) fuel:

$$d^t = \sum_{j \in J} \alpha_j \cdot d_j^t, \quad t \in T. \tag{13}$$

      In such a case instead constraint (11) one shall add constraint:

$$\sum_{j \in J} \alpha_j \cdot x_j^t \geq d^t, \quad t \in T. \tag{14}$$