The model uses the following notation:

M = Modules/subsystems of a product $\{1, 2, \dots, N_m\}$

S = Suppliers assigned to a Module $\{1, 2, \dots, N_s\}$

F = Focal Company assigned to a module

The decision variables are as follows:

X_{ms} = Variable indicating supplier s is assigned to module m (Binary variable). 1 indicates that the supplier s has been assigned to a particular module m, and 0 – otherwise

X_{mf} = Variable indicating that the FC retains Module m (Binary variable).

The parameters are as follows:

C_m = Estimated complexity of module m. This is modeled as the sum of the internal geometric/physical connections between chunks and the number of chunks in the module, derived from the DSM. It influences the collaborative costs of developing the module as explained in the objective function below.

U_{ij} = Estimated collaborative efforts of FC and suppliers for modules i and j if they are not developed by the same supplier. This is modelled as the sum of interactions between modules and the number of modules in the DSM.

$$ICC = \vec{X_f}\,\vec{C} + \sum_{j=1}^{N_s} \vec{X_s}\,\vec{C}$$

(1)

Where $\vec{X_f} = [\, X_{1f}\ X_{2f}\ X_{3f}\ \dots \dots \dots X_{mf}\,]$, $\vec{C} = [C_1\ C_2\ C_3\ \dots \dots \dots\ C_m]^T$, $\vec{X_s} = [\, X_{1s}\ X_{2s}\ X_{3s}\ \dots \dots \dots X_{ms}\,]$.

$$ECC = \sum_{i=1}^{N_m} \left(X_{if}\,\vec{U_i}(I - \vec{X_f}) + \sum_{j=1}^{N_s} X_{ij}\,\vec{U_i}(I - \vec{X_j}) \right)$$

(2)

Where $\vec{U_i} = [U_{i1}\ U_{i2}\ U_{i3}\ \dots \dots \dots\ U_{ij}]^T$ and I is an N_m dimensional vector of 1.