Hypothetical Case Example

A two-story structural steel commercial building with a gross floor area of approximately 45,000 ft² is considered to demonstrate the use of the set of equations in Section 4.4. The building is designed for disassembly (DfD) and consists of five prefabricated modules, two of which are reused. The reused modules are Module 1, which required minor cleaning, and Module 2, which needed moderate surface treatment and strengthening.

The construction is scheduled to be completed in 12 months. However, to accelerate the construction time, the contract includes an incentive clause that provides 2,000 CAD per day for reducing the construction duration. Fabrication of Module 1 and Module 2 would normally require 12 and 15 days, respectively. By reusing these modules instead of fabricating new ones, 27 days were saved, resulting in schedule savings of 54,000 CAD. The project, by using these 2 modules, also saved waste-handling costs, estimated at 140 CAD per tonne for haulage over 60 km, yielding an additional 25,200 CAD in savings.

The table below summarizes the pertinent data for each module used in the construction of the building.

Module #	Module 1	Module 2	Module 3	Module 4	Module 5
Status	Reused	Reused	New	New	New
Weight (tonne)	80	100	100	80	90
Transport (km)	60	60	200	200	200
E (tco_2-e/t)	0.25	0.25	1.7	1.7	1.7
E_{total} (tco_2-e)	20	25	170	136	153
Unit cost (CAD/t)	1,280	1,280	1,600	1,600	1,600
Total cost (CAD)	102,400	128,000	160,000	128,000	144,000
F	0.6	0.7	1	1	1
P	0.9	0.8	1	1	1
L	0.8	0.85	1	1	1

Calculations of key metrics using equations S1 to S5 of Section 4.4

Based on the data of this hypothetical case example, Equations S1–S5 are used as follows:

All variables and symbols used in these equations are defined as follow:

$i = module\ index\ (1\ to\ n)$; $n = total\ number\ of\ modules$;

$Weight_{reused,i} = weight\ of\ reused\ module\ i\ (tonnes)$;

$Weight_{total,i} = total\ weight\ of\ module\ i\ (tonnes)$;

$E_{new,i} = emissions\ of\ new\ fabricaed\ module\ i\ (tCO_{2-e}\ per\ tonne)$;

$E_{reused,i} = emissions\ of\ reused\ module\ i\ (tCO_{2-e}\ per\ tonne)$;

$Cost_{new,i}\ and\ Cost_{reused,i}\ = unit\ material\ costs\ \left(\frac{CAD}{tonne}\right)\ for\ new\ and\ reused\ modules$;

$Savings_{waste,i} = avoided\ waste - handling\ cost\ for\ reused\ module\ i$;

$Savings_{schedule,i} = schedule - incentive\ savings\ from\ reusing\ module\ i$

Equation S1 – Modular Reuse Ratio (MRR)

$$\mathrm{MRR}_{Project}(\%) = \left(\frac{\sum_{i=1}^{n} Weight_{reused,i}}{\sum_{i=1}^{n} Weight_{total,i}}\right) \times 100$$

$$\mathrm{MRR}_{Project}(\%) = \frac{80 + 100}{80 + 100 + 100 + 80 + 90} \times 100 = \frac{180}{450} \times 100 = 40\%$$

Equation S2 – Carbon Savings (CS)

$$\mathrm{CS}_{project}(\mathrm{tCO}_{2-e}) = \sum_{i=1}^{n} (\mathrm{E}_{new,i} - \mathrm{E}_{reused,i})(\mathrm{tCO}_{2-e}/\mathrm{t}) \times \mathrm{Weight}_{reused,i}\ (t)$$

$$\mathrm{CS}_{project} = (1.7 - 0.25)\ \mathrm{x}\ (80 + 100) = 1.45\ \mathrm{x}\ 180 = 261\ \mathrm{tCO}_{2-e}$$

Equation S3 – Lifecycle Cost Savings (LCS)

$$\mathrm{LCS}_{project}(\mathrm{CAD}) = \sum_{i=1}^{n} [(\mathrm{Cost}_{new,i} - \mathrm{Cost}_{reused,i}) + \mathrm{Savings}_{waste,i} + \mathrm{Savings}_{schedule,i}]$$

(a) **Material cost differential**

(Total Cost_{new} − Total Cost_{reused}) x (Total Weight_{reused})

(1,600 − 1,280) CAD/t × (80 + 100) t = 57,600 CAD

(b) **Waste handling savings**

Rate assumed is 140 CAD/t for haulage ≥ 60 km

Total waste savings = (Module 1 weight + Module 2 weight) x waste handling rate per tonne

= (80t + 100t) x 140 CAD/tonne = 25,200 CAD

(c) **Schedule savings**

27 days × 2,000 CAD/day = 54,000 CAD

$\mathrm{LCS}_{project} = 54{,}600 + 25{,}200 + 54{,}000 = 136{,}800$ CAD

Equation S4 & S5 – Material Circularity Indicator (MCI)

Per module:

$\mathrm{MCI_j} = \mathrm{F_j} \times \mathrm{P_j} \times \mathrm{L_j}$

$\mathrm{MCI}_{Module1} = 0.6 \times 0.9 \times 0.8 = 0.432$

$\mathrm{MCI}_{Module2} = 0.7 \times 0.8 \times 0.85 = 0.476$

Project-level:

$$\mathrm{MCI}_{\mathrm{project}} = \frac{\sum_{j=1}^{m}(\mathrm{MCI}_j \times \mathrm{Weight}_j(\mathrm{tonne}))}{\sum_{j=1}^{m}\mathrm{Weight}_j\ (\mathrm{tonne})} = \frac{(80 \times 0.432) + (100 \times 0.476)}{80+100} = 0.456$$

It should be noted that the example utilized modular construction to facilitate and simplify the calculations of the above equations. In other cases where deconstruction is applied at the structural steel member level, the above equations can be applied in the same manner. In such cases the calculations will remain identical to those applied above. Clearly in such practical cases a simple excel sheet application can be developed to facilitate the application of the five equations used above.

It should be noted that these calculated metrics can be used to track and report how well the set targeted objectives, for reduction of carbon emissions and LCC, are met in each city and by each project development organization.