The assessment of carbon footprint in interior decoration and construction in Taiwan

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Abstract. Global warming is more and more serious due to Carbon dioxide emission. This study focuses on the carbon footprint in interior decoration and construction via whole life cycle periods. The assessment is calculated by carbon footprints per square meter of indoor area in the unit of kgCO2e/m² during the design procedure. The percentage of carbon decreasing is related with the design value and standard value. This study collected and analysed the carbon dioxide emission in every parts of interior decoration and construction as the database to be the standard value. And established the evaluated equations for further assessment by interior designers.

1. The first section in your paper

Global warming is more and more serious due to Carbon dioxide emission. There are many ways to control the carbon emission via industry procedure, but there is no assessment in interior decoration and construction. This study focuses on the carbon footprint in interior decoration and construction via whole life cycle periods. The assessment method called Interior Renovation Carbon Footprint Evaluation System, ICF. For simplified evaluation system, only 3 parts in (1) material and construction in new decoration or construction, (2) renewal decoration or construction, (3) demolition and wastes treatment (disposal), are evaluated in ICF system, as shown in Fig. 1.

The carbon footprints of interior renovation are evaluated by the materials, transportation and construction, which are classified into 5 parts of interior space, for instance, partition constructs (walls in RC, bricks, or constructed with building are excepted), surface of walls (pasted materials on the wall, except removable materials, such as curtain, painting), floors (fixed on the slabs, including sub flooring and surface boards), ceilings (fixed on the construction, except piping system and lighting system), and system furniture (fixed on the walls and floors, also include installed on kitchen and bathroom). These 5 parts are following the checked items of interior decoration Carbon Footprint of Product Category Rule, CFP-PCR in Environmental Protection Administration, Taiwan[1]. Templet decoration or construction inner building, removable furniture, equipment, facility, doors and windows are not included in this assessment system. This system is also not following the PAS2050[2] and avoids the parts in building construction and Landscape construction for repeat evaluation.
The lifecycle evaluation (LCi) separates into 3 consuming levels with 5 parts in interior space, high consuming level in 5 years, middle consuming level in 10 years, and low consuming level in 20 years. The consuming level years are considered by the building lifecycle years in 60 years. And renewal times standard (RTi) is considered by the decorated material duration in whole life, if the material duration could be equal or longer than the building material, it could be set as no replacement.

There are 2 requirements for health and energy saving in ICF assessment. Health requirement is related with green material without toxic compound. Energy saving requirement is focused on lighting density assessment for avoid over light design and energy consumption (LPD in Green build code of Taiwan). These 2 requirements are good for human for long time staying and less earth impacts.

2. ICF evaluation system
The interior decoration and construction in Taiwan normally focuses on woodwork (carpenter), masonry (mason, plasterer), and ironwork (ironsmith). Manpower is not including into footprint evaluation by the regulation of PAS2050, therefore only woodwork and ironwork are included into ICF evaluation system, but material and procedure are considered as one part in this system.

The electric power consumption usually follows the working period in the woodwork and ironwork. If the work period and construction carbon emission density could be collected, the carbon footprint should be defined. The construction carbon emission density means the construction site consuming CO₂ via power, material, transportation, and energy by one carpenter or ironsmith works one day, unit in “kgCO₂e/per person per day”. This is the function for collecting carbon footprint data by power consumption in “kW/ per person per day” and transferring into kgCO₂e/ per person per day in the construction site. When the construction carbon emission density was curtained, the standard working period was also defined as “per person per day/ m²”, or “per person per day/ m²”. Both of construction carbon emission density and standard working period evaluation are organized as construction carbon footprint standard in “kgCO₂e/m²” or “kgCO₂e/m²”. Finally, this study invites 6 senior workmen in the field of interior decoration or construction to check their working period by their long term experience to define the standard of construction carbon emission density into different parts of work.

Regarding to the lifecycle assessment in ICF, there are 3 parts in this assessment as shown in Fig. 1. The carbon footprint could classify in 3 parts, such as (1) material and construction in new decoration or construction (CFmc), (2) renewal decoration or construction (CFrm), (3) demolition and wastes treatment (disposal) (CFwr). The total carbon footprint (TCF) of interior decoration or construction could be calculated as Eq.1.

\[
TCF = CFmc + CFrm + CFwr\quad (\text{kgCO}_2\text{e}) \quad \text{(Eq.1)}
\]

3. ICF assessment level and Case study
After ICF assessment calculation, there is a score to know the carbon footprint (kgCO₂e/m²) in the case, but we don’t know its performance. ICF assessment level presents the performance comparing to the standard, such as diamond, gold, silver, bronze, and normal level. The construction carbon emission density in general material and procedure was set as standard, as shown in Table 1. The percentage of carbon footprint reduce (CFR) in specific value of Design case carbon footprint (CFI) and Standard case (CFI’) carbon footprint. The assessment level is evaluated in Eq.2 to Eq.4.

\[
\text{CFR} = \left( \frac{CFI - CFI'}{CFI'} \right) \times CFI' \quad \text{(-)} \quad \text{(Eq.2)}
\]

\[
CFI = \frac{TCF}{AI} \div \frac{\text{LC}\quad \text{(kgCO}_2\text{e/m}^2\cdot\text{yr)}} \quad \text{(Eq.3)}
\]

\[
CFI' = \frac{TCF'}{AI} \div \frac{\text{LC}\quad \text{(kgCO}_2\text{e/m}^2\cdot\text{yr)}} \quad \text{(Eq.4)}
\]

,where AI means total floor area in this case, LC is standard of lifecycle period (yrs), TCF is total carbon footprint (kgCO₂e/LC), TCF’ is total standard carbon footprint (kgCO₂e/LC).
### Table 1 Five parts of material and its standard of carbon footprint (kgCO₂e/m²)

| BL | Item | Construction | CFi | SCP |
|----|------|--------------|-----|-----|
| Partition constructs (CFwci) | Light partition wall | 1. Double sides Gypsum board in 1.2cm | 5.16 | 18.89 (Standard) |
| | | 2. Upper and Under U-type Steel in 75*40mm | 7.47 |
| | | 3. C-type steel column in 70*40*0.8mm at 30cm | 3.31 |
| | | 4. Glass wool infill 5cm | 2.53 |
| | | 5. Procedure (Electric Power) | 0.42 |
| Surface of walls (CFwdi) | Paint | 1. Paint 0.294kg/m² | 1.22 | 1.68 |
| | | 2. Filled soil 1.35kg/m² | 0.46 |
| Floors (CFfi) | Tiles on thick base | 1. Tiles in 1cm | 15.09 | 23.19 (Standard) |
| | | 2. 1:3 Cement mortar in 4cm thick base | 18.1 |
| Frame Ceilings (CFci) | Hanging Gypsum board | 1. Gypsum board in 9mm | 1.93 | 4.23 (Standard) |
| | | 2. Hanging ceiling with Lauan (0.3*0.45cm@25cm) | 1.85 |
| | | 3. Procedure (Electric Power) | 0.45 |
| Bundles of panels (CFBi) | Melamine board | 1. Single side 6mm melamine board in back | 4.75 | 43.08 (Standard) |
| | | 2. Double sides 18mm melamine board as frame | 36.94 |
| | | 3. Procedure (Electric Power) | 1.39 |
| Doors (CFDi) | Melamine board | 1. 18mm melamine board | 14.43 | 14.43 (Standard) |
| Countertop (CFTi) | Acrylic artificial stone | 1. Acrylic artificial stone 1.2cm | 70.69 | 79.52 (Standard) |
| | | 2. Lumber core board 1.8cm | 8.27 |
| | | 3. Procedure (Electric Power) | 0.56 |
| Shelves (CFSi) | Shelves with surface | 1. Single side 6mm melamine board | 4.75 | 8.59 (Standard) |
| | | 2. Lumber core board 2cm | 1.11 |
| | | 3. Support by Lauan (0.0064m³/m²) | 2.52 |
| | | 4. Procedure (Electric Power) | 0.21 |
| Metal frames | Open frames | 1. Square steel pipe with coating 12.4m | 1.36 | 15.79 (Standard) |
| | | 2. 18mm melamine board | 14.43 |

*Only representative items of database

For check the ICF in different type interior decoration, 18 cases ware evaluated and checked in residential buildings, office buildings, public buildings, commercial buildings, as shown in Fig.2 (CFI) and Fig.3 (CFR). The CFI of residential building and public building is around 2.0-10.0 kgCO₂e/m²·yr, but the CFI of commercial buildings is higher in 20-30 kgCO₂e/m²·yr. In these 18 cases, CFR could be 19.6%-77.9%, normally around in 19.6%-44.5%, only school building in 53.1%-77.9%.

According to the results of case study in CFR evaluation by Eq17, the figure 4 shows the average CFR is 41.3% and some cases drop under 40% even lower. The CFR is set as 20% in normal level, and every 10% as the range in higher level. Due to some buildings with less decoration, their original construction carbon emission density is lower, so the basic level should be different. The normal level is set from 20% to 30% in less decoration cases, and is set from 10% to 20% in normal decoration cases.

### 4. ICF hot point assessment and Strategy

Try to select three different type building in a house, a library, and a shopping mall as the examples for indoor decoration and construction to discuss the ICF system with hot spot diagnosis and carbon reduction strategy. The design case carbon footprint (CFI) in the house, the library, and the shopping mall is 5.7, 5.8, and 24.3(kgCO₂e/m²·yr), and the percentage of carbon footprint reduce (CFR) is 42.01% (Gold level), 24.90% (Bronze level), and 19.6% (Normal level) , as shown in Fig. 4. The
reasons of the shopping mall with higher CFI are frequently renewed the many cabinets in short life cycle. In addition, the ceiling is usually decorated with light steel frame or a metal plate to have a high carbon emission. The carbon footprint proportion of each period is similar, and the percentage of new decoration or construction is higher than other period. It is because of new decoration or construction case with less renewal times and short lifecycle. Therefore, adopt the low carbon footprint construction procedure is more important.

Based on these results, the percentage of carbon footprint is ranked by floors, system furniture, ceilings, and surface of walls, and the material and procedure could be selected with low carbon footprint objects. The designer could select the low carbon footprint material in high percentage part, such as floors to reduce the carbon footprint.

5. Conclusion
This Interior Carbon Footprint assessment is established in local carbon footprint database in Taiwan. This ICF assessment system is provided a simple evaluation of carbon footprint in interior decoration and construction for designer, and is also provide an assessment level to classify the carbon footprint decrease percentage for administrator to manage the performance.

Fig.1 Simplified ICF evaluation system in 3 parts
Fig.2 Design case carbon footprint
Fig.3 The percentage of carbon footprint reduce
Fig.4 The comparison of carbon footprint

References
[1] Carbon Footprint of Product Category Rule, CFP-PCR in Environmental Protection Administration, Taiwan, 2015
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