Study on Condition Assessment Metrics based Facilities Condition Index and Building Condition Index

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Abstract. This paper presents several types of condition assessment metrics that were used by previous literatures. The condition assessment metrics are developed to supports decision-making for stakeholders in accomplishing the maintenance priority and proposed budget-driven. These condition assessments have both advantages and disadvantages to support the building infrastructure and asset management. This paper studies two groups of condition indices which are monetary- derived and engineering-derived approach. Both approaches are well-known methods to determine the condition index of buildings or facilities. Monetary approach involved a facility condition index, FCI. The FCI can be determined through estimation of deferred maintenance listed from basic, intermediate and advanced parameters. On the other hand, the engineering-derived approach is mostly referred to the Building Condition Index, BCI. Findings focused on the critical review from the rating system, conditions and recommendations that have been used by the FCI and the BCI. It was found that the disadvantages of the facility condition index can be improved through the integration of the BCI during the process. The details and quantitative figures that can be determined from the BCI will help an efficient FCI determination. Besides, BCI approach can also be used independently to give fast and first-hand findings on the conditions of buildings or facilities to the stakeholders. In conclusion, an efficient building and asset management can be offered by considerations in combining the BCI and FCI to promote "best practice" when evaluating the condition assessment due to defects and deteriorations of assets and facilities.

1. Introduction
As stated by Mihai et. al. [1], asset management is the core element in the maintenance and management of a building. At present, asset management has expanded with time. It provides outcomes to the stakeholder who employs the tools for asset registration, monitoring the asset condition and deterioration forecast, asset valuation, life cycle economic and many others. The expansion of condition assessment metrics from the aspect of built environment in Malaysia. Every country has its own guidelines of condition assessment metrics for maintenance and management purposes, especially European countries. The condition assessment metrics is developed to support decision-making for the organisation in accomplishing the maintenance service standards.

Moreover, it is a tool to determine the physical state of buildings or facilities either in good or bad condition. Yacob et al [2] pointed out that from time to time, a building or facility needs regular inspection since it reflects the condition of the building from deteriorates and defects. The condition assessment metrics are classified into two groups which are monetary-derived and engineering-derived. The monetary approach is an economic and financial metric that consists of facility condition

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index, *FCI* and backlog maintenance. However, the engineering-derived approach is functionality and performance matrix which consists of the Building Condition Index, *BCI* and quantity of defects [3].

2. Monetary-Derived Condition
The condition assessment based on the monetary approach is called the Facility Condition Index, *FCI*. *FCI* offers an index that can describe the physical state of a building or facility and its component systems against a cost model as if a recently constructed with the beginning of their service life [4]. There are many definitions of facility condition index which are stated-in journals and guidelines. According to Parsons [4], the *FCI* measures the estimated cost of the current deficiencies and compares it to the projected Replacement Value for that system.

According to APPA [5], the *FCI* is the proposition of overall deficiency backlog cost to the building's current replacement value, *CRV*. G. Mayo and P. Karanja [6] stated that the definition of Facility Condition Assessment, *FCA* is a systematically evaluating procedure an organisation’s capital assets to project repair, renewal, or replacement needs that will conserve their ability to support the task or activities that they are appointed to contribute. *FCA* also can be referred as Condition Assessment, *CA*.

According to Weeks [7], the primary objective of the *FCA* is to identify the backlog of maintenance and capital. Besides, it can determine the overall physical condition of building systems and equipment for an individual facility and the total portfolio of the facilities. Then, reported to the individual facility assessment reports include detailed descriptions and cost estimates of the maintenance repair and capital replacement backlogs for all facilities. Finally, the goal of the *FCA* reports is to provide sufficient technical and budgetary information to enable asset management to decide on the best approach or options to maintain and sustain the facilities.

According to Mayo and Karanja [6], the data are analysed and converted into a condition value which is Facility Condition Index, *FCI* once the inspection is completed. NCES [8] stated that FCI is used to compare facilities condition and to determine its economical aspects to repair or replace the facilities. Equations (1) and (2) show general formula to calculate *FCI* and *CRV*.

\[
FCI = \frac{DM}{CRV} \times 100\% \tag{1}
\]

\[
CRV = GA \times RCSF \tag{2}
\]

Where:

*FCI* = Facility Condition Index  
*DM* = Deferred Maintenance  
*CRV* = Current Replacement Value  
*GA* = Gross Area  
*RCSF* = Replacement cost per sq.ft

Cost for the deferred maintenance is a monetary expenditure for maintenance operations and renewals on components, systems or the whole building which have been delayed. Current Replacement Value is defined as the replacement value of components, systems or the whole building [9–11]. Table 1 shows the rating scale of *FCI* with their condition description. The result scale rating in percentage from 0 to 100 which is evaluated as 0 as the best condition and 100 as very poor or critical conditions.
### Table 1. FCI Rating with description

| Ref. | Scope of CA | Estimated Area of CA, sq.ft | FCI Rating, % | Condition | Recommended Action |
|------|-------------|-----------------------------|---------------|-----------|-------------------|
| [4]  | Ferris State Uni. | 3,481,797 | 0 – 15 | Good | Maintain. |
|      | i. Academic buildings | | 16 – 25 | Fair | Functional and repairable. |
|      | ii. Administrative buildings | | 26 – 60 | Poor | Need significant attention. |
|      | iii. Etc. | > 60 | Critical | Suggest beyond useful life. |
| [7]  | Park: | 54,537,000 | 0 – 20 | Good | Minor improvement needed. |
|      | i. Playgrounds | | 21 – 30 | Fair | Some significant repairs needed. |
|      | ii. Courts | | > 30 | Poor | Major repairs needed. |
|      | iii. Parking Lots | | | | |
|      | iv. Park Roads | | | | |
| [9]  | Department of the Interior. | n.a | 0<15 | Acceptable | n.a |
|      | i. Non-heritage buildings & structure | | 15>100 | Unacceptable | n.a |
|      | ii. Heritage buildings & structures & assets | | | | |
|      | iii. Road | | | | |
|      | iv. | | | | |
| [12] | Uni. of Ottawa | n.a | 0 – 5 | Excellent | Maintain |
|      | i. Academic building | | 6 – 10 | Fair | Repair |
|      | ii. Student residence | | 11 – 30 | Poor | Replacement |
|      | iii. Ancillary | | > 30 | Critical | n.a |
|      | iv. Site services | | | | |
|      | v. Etc. | | | | |
| [13] | Uni. of Louisville | 2,476,144 | 0 – 5 | Excellent | Satisfactory |
|      | i. Classroom | | 6 – 10 | Good | Satisfactory to Remodelling |
|      | ii. Laboratories | | > 11 | Fair to Poor | Remodelling to Demolition |
|      | iii. Office | | | | |
|      | iv. Other spaces | | | | |

*n.a = not available

### 2.1. FCI Approach

The facility condition index, FCI, is a well-known and globally acceptable index in determining the building’s overall condition. The standard methodology of the FCI is shown in Figure. 1. The challenges in determining the FCI especially true during the condition survey and deferred maintenance determination. The monetary expenditure of deferred maintenance can come from very simple parameters and to the extent of complex and detailed considerations. It depends on the knowledge, experience and stakeholder needs.
Previous literature U.S. Department of the Interior [9] reported that there are six (6) maintenance decisions making for DM which are; replacement, rehabilitation, demolition, component renewal, recurring and corrective. These decisions are crucial, based on experienced engineers which conducted the condition survey and assisted by the decisions from the stakeholders. Another challenge faced is to find the actual cost of deferred maintenance.

According to Uzarski and Grussing [3], it can be confusing when the deferment or backlog cost is used as a condition metric because each will have a different acceptable deferment or backlog level. It is because each building has its own criteria which are task, functionality, size and features of its deficiencies. It is also unreasonable if assuming that a zero deferment or backlog cost [3]. Figure 2 shows different considerations in calculating the FCI. FCI is mostly calculated from the basic deferred maintenance which is based on the priority condition survey and economic considerations. Thus, there is a chance of other factors will contribute to the deficiencies of the facilities. To certain extents, it will cause other defects to not be entertained and yet caused higher costs to be spending by the stakeholders as soon as it is discovered.

![Figure 1. FCI Methodology](image)

![Figure 2. Considerations in DM for FCI calculation [6]](image)
3. Engineering-Derived Condition

The condition assessment based on the engineering approach is called the Building Condition Index, \( BCI \) or Building Condition Rating. The main objective of \( BCI \) is to resolve the issues related to the inspections due to defects and deficiencies found during the field survey [3]. According to Uzarski and Grussing [3], the structured inspection method involves few actions such as observe, identify, and record the defects that occur at building components [3]. The process of structured inspection method is conducted based on the visual inspection by using suitable instruments such as a checklist and measuring tool. According to the standard, a checklist was used to register the building details, define, describe, defects in the functional components, assess the condition of the building and recommends maintenance action [2].

According to Zubair Tajol Anuar M et al. [14], the inspectors need to examine all components of the building such as architectural, civil, mechanical, electrical and external work. Each of them has its own elements need to inspect such as structures, exterior & interior part, piping system, fire prevention, lighting & communication system and roads & outdoor water reticulation. During inspection, all observed defects and severity level for each component are recorded [3]. The severity level is known as condition index or rating that is used to determine the physical state of the building. A rating system that lessens the long description evaluation and effectively forecasts future physical state of the building. The value provided from condition rating is used to compare the condition with other components [2].

According to Pitt [15], no matter what categories of conditions are introduced, it is important that the building inspector must be well qualified to ensure the data is accurate and reliable. There are three types of method of assessment using a rating scale system such as normal rating scale, matrix rating scale and percentage rating scale which will be explained later. According to Uzarski and Grussing [3] the deficiency using \( BCI \) method is that prepared the tools such as a manually checklist and building inventory for inspection. These tools need time to prepare because to list up the component-sections that are required by building with condition index, \( CI \). The \( CI \) roll-up result will affect if missing or incomplete checklist and inventory. Then, the more complicated part is to list out the element or components of the building into a checklist and inventory.

3.1. Standard Rating Scale

The normal rating scale of building index did not have a formula or equation that can analyse the condition of the overall building. However, it can still be used to indicate the condition of each building component. Table 2 shows the rating scale of building condition which has 3 to 5-point scale for the standardised method. The standard rating scale is very general and subjective. The disadvantage of this rating scale is different assessors will give different conditions from the inspections.

3.2. CSP1 matrix scale

This type of rating system has two sets of data which are building condition and defect severity. Thus, it can be evaluated to provide a rating of the overall building condition. As the basis of this rating system is Protocol 1 (visual inspection), we called the system the protocol for condition survey \( CSP \) 1 matrix [21–22]

Table 3 shows the most common scale in the \( CSP1 \) matrix. Each reported defect is assigned a priority rating and condition. Subsequently, each rating is combined to determine the cumulative score for each distress or defects. The overall score will then match the matrix and the score will range from 1 to 20 and from 1 to 25. The overall building rating will be determined after scoring every defect or distress, which summarises the state of the building. The score for each defect is applied and divided by the total number of defects to obtain the overall rating [21]. The equation (3) is a formula for a total score of building condition.
Total Score,$s = \frac{\sum \text{Total matrix}}{\sum \text{Total defect}}$  \hspace{1cm} (3)

Total matrix = \sum \text{Condition} \times \text{Priority} \hspace{1cm} (4)

**Table 2. Standard Rating Scale**

| Ref. | Scale | Condition   | Recommended Action       |
|------|-------|-------------|--------------------------|
| [16] | 0     | Good        | Maintain                 |
|      | 1     | Fair        | Minor improvement needed |
|      | 2     | Poor        | Some significant repairs needed |
|      | 3     | Severe      | Major repairs needed     |
|      | 4     | Very Severe | Replace/demolish         |
| [17] | 1     | Excellent   | Maintain                 |
|      | 2     | Good        | Minor improvement needed |
|      | 3     | Fair        | Some significant repairs needed |
|      | 4     | Poor        | Major repairs needed     |
|      | 5     | Bad         | Replace/demolish         |
|      | 6     | Very Bad    | Replace/demolish         |
| [18] | 1     | Good        | No repair                |
|      | 2     | Fair        | Repair but not too serious or urgent |
|      | 3     | Poor        | Replace and repair immediately |
| [19] | 1     | Excellent   | Maintain                 |
|      | 2     | Good        | Minor improvement needed |
|      | 3     | Fair        | Some significant repairs needed |
|      | 4     | Poor        | Major repairs/replace/demolish |
| [20] | 1     | Very Poor   | Replace/demolish         |
|      | 2     | Poor        | Major repairs needed     |
|      | 3     | Fair        | Some significant repairs needed |
|      | 4     | Good        | Minor improvement needed |
|      | 5     | Excellent   | Maintain                 |

**Table 3. CSP1 matrix scale**

| Reference | Condition Scale | Priority scale | Total matrix/score |
|-----------|-----------------|----------------|-------------------|
| [21]      | 1: Good         | 1: Normal      | 1:1-4             |
|           | 2: Fair         | 2: Routine     | 2:5-12            |
|           | 3: Poor         | 3: Urgent;     | 3:13-20           |
|           | 4: Very poor    | 4: Emergency   |                   |
|           | 5: Dilapidated  |                |                   |
| [22]      | 1: Very good    | 1: Normal      | A:1-5             |
|           | 2: Good         | 2: Routine     | B:6-10            |
|           | 3: Fair         | 3: Repair      | C:11-15           |
|           | 4: Poor         | 4: Rehabilitation | D:16-20        |
|           | 5: Very poor    | 5: Replacement | E:21-25           |

3.3. Percentage rating scale

This type of rating has a similar five-point scale as stated on the above method and shown in Table 4. Conversely, this type of method used the components weightage or percentage with condition-based to calculate the average condition of building components. The detail of each condition category as shown in Table 4. Equation (5) is a formula to calculate the average of building condition.
Average condition, \( Cr = p_1 + 2p_2 + 3p_3 + 4p_3 + 5p_5 \)  

(5)

Where,
CR = Components rating

\( p_i \) - percentage of the component with a condition rating of \( i \).

### Table 4. Percentage rating scale [23–25]

| Condition Rating | Condition          | Action Required          |
|------------------|--------------------|--------------------------|
| 5                | Very Good          | Planned preventative maintenance |
| 4                | Good               | Condition-based maintenance |
| 3                | Fair               | Major Repair            |
| 2                | Bad                | Rehabilitation          |
| 1                | Very Bad           | Replacement              |

### 3.4. Aggregation Approach rating

For this type of method, it has the same condition rating as stated on the above method and the rating scale shown in Table 5. However, the differences between them were the calculation of the overall building condition. This method used alternative approaches to aggregating system-level condition data into a single overall value for facility condition. The alternative was to calculate a weighted average condition based on asset replacement cost. This approach requires quantifying the replacement cost for each facility component. Given these replacement costs, the average rating is calculated for each component, and an overall rating is calculated by weighting each component by the component replacement cost. The average rating for the component is calculated as follows in equation (4) and the overall facility condition rating may be expressed as (6).

\[
OR = \frac{\sum_i CR_i \cdot RC_i}{\sum_i RC_i} 
\]

(6)

Where,

OR = overall rating
CR\(_i\) = the rating for component \( i \) (refer to Eq 5)
RC\(_i\) = the replacement cost for component \( i \).

### Table 5. General Condition Assessment Rating Scale [26]

| Rating | Condition |
|--------|-----------|
| 5      | Excellent |
| 4      | Good      |
| 3      | Adequate  |
| 2      | Marginal  |
| 1      | Poor      |

### 4. Recommendations on Best Practice

Basic considerations during the determination of \( FCI \) has caused some defects and deficiencies are not properly acknowledge and entertained. It is crucial to find options that can improve the disadvantage of \( FCI \). If this is proposed, defects and deteriorations that affected building maintenance issues can be solved efficiently. To that proposed, Figure. 3 recommends as the best practice approach to increase the efficiencies in condition assessment. Integrating the \( BCI \) into \( FCI \) in efficient manners can promote such an optimum maintenance approach. The \( BCI \) will not only quantitatively calculated the \( FCI \), but it can efficiently stand-alone to the stakeholders get a first hand and speed results on the conditions of their building or facilities.
5. Conclusion
The facility condition index and building condition index served the same purpose, to determine the condition of building or facility. FCI has a disadvantage especially when leading to value deficiency backlog. BCI derived from the engineering analyses on how deterioration affects the components-section and efficiency of buildings. BCI was found as the best derivation method, accurate, and robust especially in reporting building or facilities conditions. Building and asset management should involved integrations from FCI and BCI to promote efficiency. FCI is a good condition metric-economic but not performance-based. Nevertheless, BCI is a good performance-based but not condition metric-economic. The integration of both approach can give an optimum decision-making process in building and asset management.

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