KPIs for facility’s performance assessment, Part II: identification of variables and deriving expressions for core indicators

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Abstract
Purpose – The purpose of this paper is to identify key variables that affect the quantifiable key performance indicators (KPIs) and to derive equations to measure these indicators. Qualitative KPIs are also discussed in terms of the aspects that need to be covered while carrying out qualitative performance assessment.

Design/methodology/approach – A combination of literature and an industry opinion-based qualitative approach is applied to develop equations to calculate the quantifiable KPIs. A facility asset management consulting firm is included in the process of deriving the equations. Key aspects of a facility’s qualitative performance assessment are categorized and discussed by performing a literature review.

Findings – Mathematical expressions for core performance indicators are presented and discussed along with key variables. In addition, the information needed to quantify these core indicators is also discussed.

Research limitations/implications – This paper represents the second step towards establishment of a relevant list of quantifiable and measurable core KPIs, which were identified and categorized in Part I of this paper. In Part II, the authors derive equations to quantify the core KPIs. Future research is needed to use relevant information from industry for validating these equations.

Practical implications – A need for a concise and relevant list of KPIs was identified in Part I of this paper. Part II provides an approach to quantify the core KPIs based on information that is available in the industry. This research will help facility management professionals in not only selecting the indicators of choice, but also quantifying them based on available information yielding enhanced facility management decisions with measurable facility performance outcomes.

Originality/value – This paper provides equations and variables to measure a facility’s physical, functional and financial performance using both quantitative and qualitative performance assessments.

Keywords Assessment, Asset management, Quantitative techniques, Performance indicators

Paper type Research paper
Introduction

The performance assessment of a facility is important for making future decisions. The process of performance measurement includes reviewing previous and current facilities performance and comparing them within and across similar organizations. The results of this process help organizations evaluate their facility’s contribution toward an organization’s goals, derive strategies for future endeavors and provide guidance to the management for making decisions (Amaratunga et al., 2000; Douglas, 1996). According to Cohen et al. (2001), periodic feedback about a facility’s performance is vital for continuous and consistent improvement.

The literature suggests various approaches, such as benchmarking, balanced scorecard, post occupancy evaluation, key performance indicators (KPIs), and critical success factors for the facility’s performance evaluation. Likewise, a service efforts and accomplishments (SEA) reporting is also being used for performance evaluation and quality improvement of public sector organizations (O’Toole and Stipek, 1996), which is described by Ammons (1996) as a tool for “general purpose financial reporting.” Performance measurement by utilizing KPIs ensures not only a holistic evaluation, but also provides an opportunity to the facility management professionals to select the indicators of their choice (Lavy et al., 2010). The first step in the process of performance assessment using KPIs is to identify relevant indicators that are not only measurable but also quantifiable (Varcoe, 1996; Amaratunga et al., 2000). However, the selection of performance indicators depends primarily on the type of users (e.g. facility managers, executive level management), the nature of the organization (private vs public), performance assessment focus (e.g. financial, functional, physical), and current trends and demands in the industry (Amaratunga et al., 2000; Eagan and Joeres, 1997; Cripps, 1998).

A broad list of KPIs exist that could be utilized for the performance evaluation; however, this list is extensive and some of its indicators may not be relevant, measurable, and quantifiable, or may not possess wider applicability (Shohet, 2006; Lavy et al., 2010). There is a need to identify the core indicators of performance that cover not only financial aspects but also focus on aspects such as business, organization goals, job satisfaction, work environment, environmental issues, and other non-financial qualitative aspects in a detailed manner (Amaratunga et al., 2000; Douglas, 1996; Cripps, 1998; Eagan and Joeres, 1997; Epstein and Wisner, 2001). One need suggested by the literature includes evaluating the efficiency with which the facility performs its maintenance and replacements. One conventional focus of facility maintenance is on reducing maintenance expenditures while providing a healthy, comfortable and safe workplace for occupants (Horner et al., 1997; De Groote, 1995; Kutucuoğlu et al., 2001; Shohet and Lavy, 2004; Tsang et al., 1999; Office of the Legislative Auditor, 2000). It is also vital to determine how often a facility is replacing its components that are expired or nearing the end of their service life (APPA et al., 2003; Kinnaman, 2007). The Facility Condition Index (FCI) is an indicator often used for the condition assessment of a facility. The FCI considers the impact of deferred maintenance as a ratio of the total current replacement value of a facility (Briselden and Cain, 2001; Teicholz and Edgar, 2001; Vanier, 2000). Apart from the facility’s maintenance, replacement, and condition, its functional suitability also must be evaluated. Typically, functional suitability relates to the provision of sufficient space in the facility and effective space management (Douglas, 1996; Douglas, 1993/1994;
Schroeder et al., 1995). Other indicators, such as indoor air quality, also have a profound impact on organizational performance as they are responsible for health, comfort and safety of building occupants. An adverse indoor atmosphere may increase absenteeism and reduce productivity, which may have business as well as financial implications (Mozaffarian, 2008; Prakash, 2005; Fowler et al., 2005).

Extensive literature is available on the topic of KPIs and facility performance assessment that can be augmented to provide a concise and relevant list of quantifiable and measurable performance indicators. Part I of this paper focused on identifying and categorizing the measurable core performance indicators. In Part II, variables that affect the core performance indicators are identified and discussed. In addition, expressions for the core indicators are derived and discussed in the light of existing literature.

Research methods
This paper builds on earlier research (Lavy et al., 2010). This research follows the process suggested by the literature to establish a broad list of performance indicators gathered from literature sources, organize them in respective categories, and condense them into a compact, yet relevant, set of core and quantifiable performance metrics (Hinks and McNay, 1999; Ho et al., 2000; Slater et al., 1997).

In Part I, the core KPIs were identified, categorized and discussed. In this paper, a review of relevant literature has been performed in order to identify the key variables that influence the core KPIs. Inputs from the facility management industry were sought to refine the variables that affect the core KPIs. The data required for calculating the KPIs are not readily available; in this research, our intent is to propose KPIs that can be calculated based on information available in the industry. Industry inputs helped in identifying variables, data which are readily available. For the purpose of evaluating a facility’s environmental performance, the LEED® Green Building Operations and Maintenance Reference Guide was selected as the prime resource for the refinement and development of the indoor/outdoor environmental quality (IOEQ) indicators. The rating system is compressed to include only 29 performance-related credits (totaling 77 possible points) by excluding all prerequisites and credits not directly associated with air quality, site conditions, energy efficiency, water efficiency, and solid waste generation, including all Regional Priority and Innovation in Operations credits. In the User Perception category, various user perception aspects suggested by the literature are gathered and classified into three major categories.

A leading facility asset management consulting firm provided major industry input. This firm globally offers:

- the provision of key facilities performance metrics;
- capital planning;
- facility condition and environmental assessment;
- real property inventory management;
- facility use and investment strategies; and
- computer-aided facility management systems consulting and information systems development.

Based on the literature opinion and industry inputs, the calculation equations for the core KPIs are derived and explained.
Literature review

Performance assessment and KPIs

KPIs evaluate the facility in terms of its overall performance toward achieving organizational goals. The process of performance assessment also provides valuable insights to make decisions, such as facility expansion, real estate acquisition, and a facility’s renovation and retrofit (Amaratunga et al., 2000; Douglas, 1996). A list of KPIs enables performing the facility performance assessment, as it provides a common platform of comparison, includes metrics that represent the key performance objectives, and helps derive strategies for decision-making (Ho et al., 2000; Douglas, 1996; Hitchcock, 2002; O’Sullivan et al., 2004). Atkin and Brooks (2000) observed that for a performance assessment, it is important to identify factors that are crucial to the success of the organization. Furthermore, these factors, which are termed critical success factors (CSFs), indicate required efforts to meet organizational goals and could consist of one or more KPIs that help management to measure, evaluate, and govern the progress. Varcoe (1996) stated that organizational goals have associated objectives which could be transformed into measures of performance evaluation to assess the organization. Moreover, this process of developing performance metrics could emerge as a result of change in the organization’s strategies, as well as in its objectives.

Studies such as Douglas (1996), have suggested a proper categorization of KPIs so that they can be applied widely and better utilized. The KPIs need to be categorized in a manner that permits the selection of a set of indicators in which professionals are specifically interested (Douglas, 1996; Ho et al., 2000). Studies such as Ho et al. (2000) and Slater et al. (1997) did not favor a large list of KPIs, and stated a need to provide a concise list of relevant performance indicators. Past performance assessment practices, which focused primarily on financial aspects, should now concentrate also on aspects such as business, organizational goals, job satisfaction, work environment, environmental issues, and other non-financial qualitative aspects (Amaratunga et al., 2000; Douglas, 1996; Cripps, 1998; Eagan and Joeres, 1997; Epstein and Wisner, 2001). The KPIs should not only be easily measurable, but also quantifiable, in order to allow comparisons (Shohet, 2003; Augenbroe and Park, 2005; Ho et al., 2000; Tsang et al., 1999; Chan et al., 2001). Performance indicators should not only possess a limited focus, but should be generalizable and hold wider applicability (Shohet, 2003; Hinks and McNay, 1999).

Indicators for facility performance assessment

The literature indicates a need to derive a succinct list of core quantifiable indicators that could be used by professionals for a holistic facility evaluation. The following sections describe the literature opinion on indicators that measure various aspects of a facility’s performance.

Maintenance efficiency. Facility management practices minimize maintenance expenditures by simultaneously operating a facility in a safe, comfortable and profitable manner (Horner et al., 1997; De Groote, 1995; Kutucuoglu et al., 2001; Shohet and Lavy, 2004; Tsang et al., 1999; Office of the Legislative Auditor, 2000). The total maintenance expenditure includes corrective and preventive functions: corrective maintenance deals with any sudden break-down of a facility or related systems, whereas preventive maintenance is planned and performed to prevent future failures. A third category of maintenance, called condition-based maintenance, is performed on
the basis of inspecting the current condition of the building or its various systems (Horner et al., 1997). Chan et al. (2001) developed and presented a preventive maintenance ratio as a vital maintenance performance indicator, which is defined as the ratio of preventive maintenance to corrective maintenance in man-hour terms. Shohet and Lavy (2004) proposed a method for maintenance performance evaluation (relating to hospital facilities) that combines four primary KPIs:

1. building performance indicator (BPI);
2. maintenance service provisions;
3. maintenance efficiency; and
4. organizational effectiveness.

De Groote (1995) proposed a set of maintenance performance metrics measured as ratios expressed in terms of human, material, and financial resources. However, the literature suggests there is still a lack of proven quantifiable measures of maintenance performance in the facility management industry, and past studies fail to provide metrics that are key in strategic decision-making (Shohet, 2006; Shohet, 2003; Adams and Smith, 2005; Chan et al., 2001).

Evaluation of maintenance performance depends on impact, efficiency, and cost effectiveness of preventive maintenance (Office of the Legislative Auditor, 2000; Dean, 2008). As Pintelon and Puyvelde (1997) explained, performance metrics are mostly ratios demonstrating effectiveness, efficiency, or productivity. Strategies for maintenance are affected by the planned maintenance budget (preventive maintenance) that cannot be determined easily (Horner et al., 1997). The current condition assessment of a facility and its different components could also guide the calculation of preventive maintenance (Office of the Legislative Auditor, 2000). Shohet (2003) asserted that building performance indicator (BPI) could be a vital indicator of a facility’s performance, if integrated with measuring maintenance efficiency through the maintenance efficiency indicator (MEI). The MEI is the most influential performance indicator that could significantly affect the strategic decision making in an organization (Pati et al., 2009a; Shohet, 2003; Shohet et al., 2008). Pati et al. (2009), and Park and Augenbroe (2003) stated that the MEI expresses the quantified efficiency with which a facility expends its resources.

Replacement efficiency. Replacement activities deal with renewing and/or replacing facilities, their systems and components, which are either damaged or nearing their service life (Rondeau et al., 2006). Replacement activities and related expenses vary each year (Office of the Legislative Auditor, 2000). Capital renewal is another indicator of future renovation activities that takes into account all of the expenses related to facility renovation (State Council of Higher Education, 2001; Fagan and Kirkwood, 1997). Capital renewal index, which is a ratio of annual capital renewal to the current replacement value, is an appropriate indicator to evaluate the replacement efficiency of a facility (APPA et al., 2003; Kinnaman, 2007).

Condition index. The National Association of College and University Business Officers (NACUBO) was among the first organizations (1991) to provide a conceptual framework for Facility Condition Index (FCI) in their publication *Managing the Facilities Portfolio* (see Rush et al., 1991) (Briselden and Cain, 2001). FCI has been
defined as a ratio of maintenance deficiency to the current replacement value (CRV) of the facility or system under study (Rush et al., 1991; Briselden and Cain, 2001; Department of Interior, 2008; Teicholz and Edgar, 2001; Uzarski and Grussing, 2001; Geldermann and Sapp, 2007; Vanier, 2000). Maintenance deficiency is the amount of deficiency in maintenance and repair work, excluding any future maintenance projections or constructions (Rush et al., 1991; Briselden and Cain, 2001; Department of Interior, 2008). CRV is the total of various costs (labor, materials and supplies) required to restore or replace a constructed facility to a condition of “as good as new” with the same size and functional capability without modification or improvements (Department of Interior, 2008). FCI values range between 0 and 1, with “0” being excellent and “1” being worst. The literature classifies FCI values to be: under 0.05 – good, 0.05 to 0.1 – fair, and above 0.1 – poor (Rush et al., 1991; Teicholz and Edgar, 2001, Uzarski and Grussing, 2001; Vanier, 2000). The amount of maintenance deficiency has a strong relationship to the physical condition of a facility (Rush et al., 1991; Briselden and Cain, 2001; Department of Interior, 2008; Teicholz and Edgar, 2001). Building users perceive the building condition through its appearance and indoor atmosphere, which may not be quantifiable. The FCI expresses the physical condition in a quantifiable manner; and hence, can be used as a condition based comparison (Briselden and Cain, 2001).

Condition can also be quantified and expressed in terms of percentage using the calculated FCI value. It can be calculated for each system individually and also for the entire facility (Watson, 2009; Uzarski and Grussing, 2001; Teicholz and Edgar, 2001). A Condition Index (CI) represents the physical condition in terms of percentage, and is calculated for a system, facility, and then, for the entire campus (Watson, 2009). Uzarski and Grussing (2001) mentioned the Engineer Research and Development Center – Construction Engineering Research Laboratory (ERDC – CERL)’s building condition index (BCI) approach that includes calculation of component section condition and component condition, which then are combined (by taking their weighted averages based on respective CRVs) to calculate the CI of a facility. Teicholz and Edgar (2001) also discussed calculation of FCI system-wise by dividing the deficiency of each system by its CRV, which then is used to compute overall condition index for the facility. The Department of Interior (2008) suggested that determination of CI must include those components only that are contributory to the integrity and functionality of the constructed facility. Components such as landscape elements, personal properties, and other appliances, if included, tend to influence the value of FCI, which does not reflect its true value.

Functional index. The amount, quality and shape of the space provided by a facility are metrics used to evaluate the basic function of a building that is to provide a protected shelter to its occupants (Douglas, 1996; Loosemore and Hsin, 2001). Space and its quality is an important factor to judge the functional quality (suitability) of a facility (Douglas, 1996). The process of space management ensures the reduction of not only over-utilized, but also under-utilized spaces (Douglas, 1993/1994; Schroeder et al., 1995). Douglas (1996) pointed out the importance of space planning and its measurement in the performance evaluation of a facility. Douglas (1993/1994) discussed floor space utility as an effective measure of spatial efficiency in a building, and lists space utility (identifying under-used and over-used spaces) among ten primary measures for effective evaluation of facility’s performance.
management could affect the organizational effectiveness of a facility negatively or positively, and thus, is vital in performance assessment of a facility (Zimmerman and Martin, 2001; Ilozor and Oluwoye, 1999; Cole and Brown, 2009). Cole and Brown (2009) further stated that a great deal of green building strategies is dependent on smart space management. The amount of space in a building could even affect the performance of its occupants. According to Hinum (1999), a study performed by Earthman (Virginia Polytechnic Institute and State University, 1996) found that space adequacy is a decisive factor in determining student performance.

Studies such as Hammond et al. (2005), discussed a space utilization assessment performed by the US Coast Guard (USCG) that evaluates space by comparing it to the space standards for that facility type. Space adequacy can be assessed in terms of the facility’s compliance with relevant standards; the USCG evolved a suit of indices that includes a space utilization index to identify under- and over-utilized spaces (Hammond et al., 2005). Hinks and McNay (1999) also developed and analyzed a list of 172 indicators, and narrowed it down to 23 key performance indicators based on their relative importance; effective utilization of space is among these 23 key indicators. Schroeder et al. (1995) revealed, after an extensive literature search, that “effective, efficient space utilization and facility management are high priorities to both corporate and facility managers.” Furthermore, Schroeder et al. (1995) asserted that it is important to identify under-used (surplus) and over-used (deficient) spaces. Loosemore and Hsin (2001) argued that the space must be assessed in terms of its contribution to the core objectives of the organization.

Indoor/outdoor environmental quality (IOEQ). According to the US Environmental Protection Agency (USEPA, 2009), Americans spend most of their time indoors; hence, the quality of indoor space affects their health and comfort significantly. Indoor Environmental Quality (IEQ) has become a grave concern among building professionals today as building occupants are exposed to a relatively higher level of pollutants for an extended time, and its impact could be seen in their performance (USEPA, 2009; Mendell and Heath, 2004). The adverse impact of IEQ on occupants’ performance severely hampers their productivity, and eventually, their turnover rate, absenteeism and mental satisfaction (Fowler et al., 2005). This, in most cases, means increased costs to include paid leaves and compensations causing severe financial impacts on an organization (Prakash, 2005). An enhanced IEQ not only increases productivity and reduces the financial burden; it also enhances confidence in the organization’s ability to provide a safe, comfortable and healthy atmosphere (Mozaffarian, 2008, Prakash, 2005; Fowler et al., 2005). Most building assessment systems around the globe, such as the national Australian built environment rating system (NABERS), the post occupancy review of buildings and their engineering (PROBE) in the UK, the comprehensive assessment system for building environmental efficiency (CASBEE) in Japan, the EcoEffect in Sweden, and the leadership in energy and environmental design (LEED) in the USA, have already incorporated IEQ as one of their primary performance indicators (Fowler et al., 2005; Malmqvist, 2008).

LEED rating system demonstrates wide acceptance among the design and construction industries and among major building rating systems that evaluate the IEQ aspects of a building (Malmqvist, 2008: Jones et al., 2009). Jones et al. (2009) revealed that the recently upgraded LEED-EB (existing building) aligns its requirements closely with operating procedures of the buildings and those
requirements work toward improving indoor environment and occupant health. Furthermore, the recently developed LEED-EBOM (existing building operation and maintenance) system incorporates IEQ aspects and provides strategies to create a healthy and productive atmosphere. According to Jones et al. (2009), LEED-EBOM has achieved a 16 percent increase in its market share (in terms of number of projects registered).

Henry (2001) discussed the importance of outdoor environment in providing recreation and nature areas, especially for students in K-12 schools. According to Bray and McCurry (2006), LEED credits regarding IEQ assume that the outdoor environmental quality (OEQ) is better than the IEQ; however, in some cases, outdoor air could be of poor quality, and thus, indoor as well as outdoor sensors must be used to assess both air qualities.

Absenteeism and user perception. As discussed in the earlier section, the built environment may significantly affect occupant performance. Absenteeism, which may result from adverse quality of the built facility, could be seen as one indicator of the level of facility’s performance (Fowler et al., 2005). In facilities such as schools, a positive indoor atmosphere may enhance students’ performance, influencing their learning (Young et al., 2003; Olson and Kellum, 2003; Brooks-Pilling and Wright, 2005). Indoor air quality aspects, such as pollutants levels, carbon dioxide levels, humidity, temperature, and daylighting, can significantly affect the indoor atmosphere (Olson and Kellum, 2003; Brooks-Pilling and Wright, 2005; Schneider, 2002). Studies conducted by institutions such as the Thomas Jefferson Center for Educational Design at the University of Virginia, and the US District Court, Northern District of California (by Biegel, 2000), indicated that students’ performance in schools closely relates to their rate of absenteeism, which is affected by the quality of the indoor atmosphere.

Organizations must recognize whether facility users (clients, customers, or employees) are satisfied with the facilities, and understand the facility’s performance from a user’s perspective (Tucker and Smith, 2008). Facility management practices, such as balanced scorecard, emphasize assessing a facility’s performance from four perspectives, two of which (customer and internal business processes) relate to user satisfaction. Hassanain (2008) emphasized the importance of assessing fire code compliance and maintenance practices of fire safety systems in order to ensure life safety in an indoor environment.

Findings

Maintenance efficiency indicator
The Facility Condition Index incorporates a comparison of total deficiencies against current replacement value (CRV); however, the contribution of maintenance and replacement in the total deficiency is not clear. Thus, an individual analysis of maintenance and replacement expenditure is required to fully understand the deficiencies. It is assumed that the total deficiency in maintenance expenditure needs to be compared against the CRV of the system or component under study in order to evaluate the maintenance performance individually. Thus, the objective of this indicator is to assess the performance of a facility’s maintenance program in order to examine how efficiently the maintenance is carried out.

The basic assumption in deriving these expressions is that the maintenance expenditure is mostly for preventive and corrective types of maintenance.
Furthermore, prioritizing a facility’s maintenance expenditure is vital and could improve the overall condition of the facility. It is also assumed that an effective maintenance program is based on data points (such as, indicator of maintenance efficiency) and trends in maintenance (expressed by corrective and preventive maintenance, or actual and expected maintenance). The following paragraphs outline the variables and indicators that are expected to provide proper guidance to a facility’s maintenance program.

**Maintenance expenditure.** The total maintenance expenditure includes both scheduled (preventive) and unscheduled (corrective) maintenance. The scheduled maintenance is assumed to remain the same (adjusted to the rate of inflation) throughout a building’s life cycle, while the unscheduled portion is uncertain, unpredictable, and might differ significantly from one year to another. The preventive maintenance could be determined with a degree of certainty and accuracy, based on past records of maintenance, or based on cost data catalogs, such as the RS-Means and the Whitestone Research. Determining corrective maintenance is, however, difficult and uncertain. The total maintenance cost is expressed by:

\[
\text{Total maintenance expenditure} = M_c + M_p
\]

Where, \(M_c\) is the corrective maintenance expenditure, and \(M_p\) is the preventive maintenance expenditure.

**Maintenance efficiency indicator (MEI).** The term deferred maintenance (DM), for the purpose of this paper, is assumed to include only maintenance activities (excluding replacement of any expired system or component). As mentioned earlier, the actual amount of deferred maintenance needs to be evaluated against the expected deferred maintenance in a given period. The spending percentage on deferred maintenance (SDM), which is a ratio of actual to targeted deferred maintenance, could provide this evaluation of maintenance performance. The maintenance performance of a facility can then be quantified as MEI by using SDM and the condition index (CI). The MEI can be defined as the ratio of SDM to CI of a facility in a given period. MEI can be derived as:

\[
\text{MEI} = \frac{SDM}{CI} \times 100
\]

\[
SDM = \frac{DM(Actual)}{DM(Targeted)} \times 100
\]

The MEI can be calculated for a given point in time as well as for a specific period of study. The MEI demonstrates the impact of a facility’s maintenance performance over its CI. This indicator acts as a baseline for assessing the efficiency of a facility’s maintenance program.

**Corrective to preventive maintenance ratio (CPR).** This ratio is significant in identifying how the corrective maintenance expenditure is compared against the preventive maintenance expenditure. It also indicates the relative proportion of each in the total maintenance expenditure. Thus, this ratio can be termed as:

\[
\text{CPR} = \frac{M_c}{M_p}
\]
The CPR demonstrates the trend of a maintenance program, and guides a facility manager toward achieving the desired MEI. CPR is only useful if calculated for a longer period of time (e.g. several years) to identify the pattern or trend of maintenance expenses.

Apart from the FCI, it is vital to analyze the contribution made by a facility's maintenance and replacement program individually in the current facility condition. MEI provides the assessment of a facility's maintenance program against the CRV. Furthermore, it is significant for a facility to aim for a desired condition by directing its maintenance expenses toward that same course of action. By providing data points, the MEI could help decision-makers generate changes in the trend of maintenance spending. The CPR can also be used to present a trend in maintenance expenses, which needs to be analyzed in conjunction with the current MEI.

Replacement efficiency indicator (REI)

Like MEI, replacement expenditure also needs to be evaluated individually to examine the contribution of the replacement program in the building's current FCI. Comparing the total replacement expenditure against the total cost of all expired systems at the end of the year is the basis for calculating the REI. Thus, the objective of REI is to assess replacement efficiency of the built facility. Two aspects of replacement are important: one is replacement expenditure, and another is the replacement schedule. Like MEI, REI could also be calculated annually, taking into account the schedule of replacement.

It is assumed that the building systems and components considered for calculating the total cost of expired systems possess a service life shorter than the building itself. Hence, building systems and components with a service life equal to or greater than the building could not be included in the calculation. Furthermore, the system or component replacement cost is assumed to be capital renewal (replacement expenditure) made at the end of the year. The REI can be expressed as:

$$REI = \frac{\sum_{n} Cap. \text{ Re} \cdot n.(\$) \times 100}{\sum Exp.(\$)}$$

Where the sum of capital renewal is the actual replacement expenditure (for building systems and components) made in the year for which the study is conducted. The denominator of the above expression is the sum of total cost of expired systems and components during the same year under study. REI is, therefore, a ratio, where a value of one indicates that the full replacement is performed (as per amount of building systems and components expired.) REI values of less than one or more than one indicate that the facility is spending less or more than the cost of expired systems and components in that year, respectively. Like MEI, this ratio can also be expressed as a percent by multiplying it by 100.

REI is significant in the sense that it expresses the efficiency of a built facility’s replacement program separately from the maintenance effect. Unlike the MEI, instead of using the CRV value, the REI evaluates the total actual replacement expenditure against the cost of all expired systems and components. Thus, it indirectly compares actual to expected replacement expenditure. The impact of REI and MEI can be seen in the calculated value of FCI, which takes into account the total deficiencies and CRV.
Functional index (FI)
The functional index (FI) is used to communicate the functionality of a space, building or campus, as well as deficiencies of a space, building or campus using a unit less ratio. This index compares gross square footage required for certain types of spaces (based on a predetermined specification or desired area) to the actual area. The functional index can be applied on a space-by-space basis, applied to a building as a whole, or applied to an entire campus.

There are several assumptions to consider when qualifying the functional index performance indicator. The first is that the minimum acceptable threshold for space must be set at a level in which the classroom would be functionally unfit for learning or teaching. Another assumption is that FI should be reviewed at multiple levels: classroom, building, school, and district. These different views will give a more accurate picture of what is causing the functional deficiency, as well as offer the most pragmatic solution.

The variables for FI include:
- total required classroom area;
- total actual classroom area;
- number of classrooms; and
- cost per square foot of new construction of classroom space (can be obtained from sources such as cost data catalogs).

These variables need to be analyzed by classroom type, as different classroom types may have different space and functional requirements. The formula for functional index states that functional index equals the total measured classroom area divided by the total classroom area required by either a specification or a number desired by the user. Note that classroom area is used in the “Total area actual” term, not gross area. This provides a more conservative estimate in that corridors and other common areas are not counted when calculating the “Total area actual.”

\[
FI = \frac{\text{Total Classroom Area (by classroom type)}_{\text{Actual}}}{\text{Total Classroom Area (by classroom type)}_{\text{Required}}}
\]

Another formula involving FI is the Building FI, which is different than FI in that it takes an entire school building into account rather than one space. This capability is significant because it allows the user to diagnose and address configuration issues in a school. These issues can lead to deficient functional indexes that can be fixed by reconfiguring existing space rather than constructing new space. The formula for determining building FI is given below.

\[
FI = \sum_{\text{Building}} \left( \frac{\text{Total Classroom Area (by classroom type)}_{\text{Actual}}}{\text{Total Classroom Area (by classroom type)}_{\text{Classroom}}} \right) \times \# \text{ of Classrooms (by classroom type)}
\]

The output for the FI formula is based on whether the value is greater than or equal to one, or less than one. If the FI is greater than or equal to 1, the space is functionally adequate and the output will be the ratio. If the FI is less than 1, the space is
functionally deficient, and the output will be the total area required multiplied by the cost per square foot of construction of new classroom space. This value would reflect the cost to correct the functional deficiency in dollars. The deficiency dollar estimate is a conservative estimate, as it assumes, for a deficient space, that an entirely new space would need to be constructed instead of simply adding on to the existing space to make up the difference in area. For example, a space that is deficient by two square feet would have the same deficiency dollars as a space that is deficient by 200 square feet, since an entirely new space would need to be constructed to correct the deficiency. Another aspect that could also define a functional efficiency of a school facility is annual enrollment, which can help determine whether the school is over or under capacity. A student-to-teacher ratio (or pupil-to-teacher ratio, PTR) can be used to determine an indicator expressing functional efficiency in terms of enrollment.

Indoor/outdoor environmental quality (IOEQ) indicator
The built environment has incontrovertible effects not only on the health, safety, and productivity of building occupants, but also on the elemental systems ecology of the natural world. Acknowledging said effects, an environmental metric evaluating the impacts of building physicality, resource consumption, and operations efficacy on indoor and outdoor environmental quality is considered vital to a holistic assessment of overall facility performance. This is because; consequential risks are associated with poor indoor air quality, site conditions, energy demand, water use, and solid waste generation.

The indoor/outdoor environmental quality (IOEQ) indicator seeks to incorporate measurements, calculations, and green building benchmarking standards that assess a facility’s environmental performance. The IOEQ indicator is calculated based on the measurements, metrics, and benchmarking standards established in the LEED® Green Building Operations and Maintenance Reference Guide (USGBC, 2009). For the purposes of data collection and analysis, the metrics were converted into a spreadsheet calculator that mimics the dynamic credit templates for submitting project documentation available only to registered LEED® project team members.

The calculator is organized by credit and by category, highlighting the variable inputs, reference tables, data collection forms, and resulting point values. An example can be seen in Figure 1, which contains the calculation for Sustainable Sites, Credit 5 – Site Development: Protect or Restore Open Habitat, where various formulas and calculations are embedded in the spreadsheet calculator. Though all calculations, benchmarked standards, and associated references are too numerous to define herein, they can be found in the USGBC LEED® Green Building Operations and Maintenance Reference Guide (USGBC, 2009).

The IOEQ spreadsheet calculates the number of points achieved overall per environmental category. Since the IOEQ abbreviated version of LEED® includes 29 of the 58 credits originally outlined in the Green Building Operations and Maintenance Reference Guide, totaling 77 out of 110 maximum possible points, the corresponding certification ratings were proportionately scaled as follows:

- Certified – 28 Points.
- Silver – 35 Points.
- Gold – 42 Points.
- Platinum – 56 Points.
While these certification levels are not included directly in determining the facility performance index, they give some indication of the level of achievable LEED® certification should the owners and/or facility managers decide to submit official application to the program.

**User perception**

Surveys are one of the most common data collection methods to investigate certain issues. Facility managers do not give much importance to the perceptions of inhabitants of a built facility, as they are more interested in the technical performance of a machine rather than the perceptions of its users (Fleming, 2005). There are two approaches to data collection regarding human perception, namely, subjective and objective. The objective approach, on one hand, involves direct observation by an external observer; the subjective approach, on the other hand, seeks perceptions of a building’s inhabitants. Preiser (1995) asserted that three levels of post occupancy evaluation must be carried out:

1. health, safety and security aspects;
2. functionality and efficiency aspects; and
3. psychological, aesthetic and socio-cultural aspects.

**Figure 1.** Calculation for sustainable sites credit 5.0
<table>
<thead>
<tr>
<th>Source</th>
<th>Health, safety and security</th>
<th>Functionality and efficiency</th>
<th>Aesthetic and socio-cultural</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEFPI (2007)</td>
<td>Maintenance and serviceability (human comfort and work safety)</td>
<td>Learning and environment</td>
<td>Sustainability</td>
</tr>
<tr>
<td>Hygge and Lofberg (1999)</td>
<td>Light, noise, temperature, ventilation</td>
<td>Space, windows</td>
<td>View out, privacy, general environment</td>
</tr>
<tr>
<td>Turpin-Brooks and Viccars (2006)</td>
<td>Internal environment, citizen satisfaction</td>
<td>Use, access, space, performance, engineering, construction</td>
<td>Urban and social integration, character and innovation</td>
</tr>
<tr>
<td>Turpin-Brooks and Viccars (2006)</td>
<td>Internal environment</td>
<td>Use, access, space, performance, engineering, construction, form and material</td>
<td>Urban and social integration, character and innovation, form and material</td>
</tr>
<tr>
<td>Turpin-Brooks and Viccars (2006)</td>
<td>Personal control, comfort, noise, overall comfort, health, lighting</td>
<td>The building overall, quickness of response, response to problems, productivity at work, your desk or work area, travel to work</td>
<td>Travel to work</td>
</tr>
<tr>
<td>Zimring (2010)</td>
<td>Quality of work life, personal productivity, psychological and social well being</td>
<td>Operating/maintenance cost, cost of building related litigation, resale value of property, rentability of space, process innovation, work process efficiency, product quality, time to market</td>
<td>Public image and reputation, customer satisfaction, community relationships</td>
</tr>
<tr>
<td>Fleming (2005)</td>
<td>Availability of natural light, security of personal possessions, temperature changes, effect of solar glare, ability to see out, informal relaxed atmosphere, general background noise, quiet rooms, variations in noise level, mobile phone noise, indoor relaxation area, internal visibility, circulation space noise, occupation density, privacy, hub noise, personal control of temperature</td>
<td>Access to printers; Quality of artificial light Amount of desk space; Window proximity; Formal meeting facilities; Quiet rooms; Support facilities; Intranet information; Workspace ownership; Personal storage; Outdoor areas; Catering; Location in building; Entrance impact</td>
<td>Casual meeting areas; Feeling of equality; Internal visibility; Internal aesthetics; Access to colleagues</td>
</tr>
<tr>
<td>Tucker and Smith (2008)</td>
<td>Personal control, privacy, personalization</td>
<td>Windows and lighting</td>
<td>Interior planting, color windows and lighting</td>
</tr>
<tr>
<td>Saidi (2007)</td>
<td>Accessibility, safety, internal views, housekeeping and cleanliness, physical comfort, surrounding environment</td>
<td>Signage, layout, waiting time and waiting rooms, treatment</td>
<td>Image of the hospital building, privacy and respect for patients, space requirements, support of family and friends</td>
</tr>
</tbody>
</table>

**Source:** Based on Preiser (1995)**
In post occupancy evaluation, user feedback is sought in areas such as environmental, lighting, colors and finishes, corridors and circulation spaces, fixtures and fittings, security, entrances, social spaces, dining areas, external spaces, learning spaces, libraries, communication, storage, changing rooms, etc. These areas, when compared with the levels of post occupancy evaluation suggested by Preiser (1995), fall into any of the three levels shown in Table I.

Conclusions
Facilities performance assessment is important for an organization to make and justify future decisions. KPIs assist in carrying out performance assessment in an organized and selective manner. Studies have identified a variety of KPIs that can be used for assessing a facility’s performance; however, the existing list is extensive and includes indicators that may not be measurable or quantifiable. Also, not all indicators may be relevant to the specific purpose and scope of each study. In addition, most of the proposed indicators focus primarily on financial aspects of a facility. This study aimed at developing a concise but relevant list of KPIs, which are quantifiable, and which can assist with assessing facility performance holistically.

With the intent of including only core KPIs, this paper focused on indicators that measure the physical condition, functional ability, and recurring activities such as maintenance and replacement in a facility. A building’s physical condition can reveal how well the maintenance and replacement activities are being performed. The maintenance aspect of a facility’s performance has been discussed in numerous studies and several indicators have also been proposed. However, most of the proposed indicators are either not quantifiable or not able to demonstrate the maintenance efficiency with which the facility is carrying out its maintenance. While little effort has been made to evaluate the replacement activities in a facility, the FCI measures the combined effect of maintenance and replacement on a facility’s condition in the form of a ratio. Functional aspects have been seldom emphasized in the existing performance assessments. This paper developed four quantifiable indicators that relate to a facility’s condition, functional performance, maintenance, and replacement schedule, in addition to qualitative indicators that measure indoor/outdoor environmental quality and user perception. These six indicators can support facility management professionals who are interested in a holistic performance evaluation of a facility.

One aspect of maintenance that still needs to be covered is the fraction of corrective and preventive maintenance in the total maintenance expenditure. The impact of not performing the preventive maintenance on the physical condition of the building should be analyzed. In the future, the authors intend to perform case studies of facilities to validate the equations derived for each of the four quantitative indicators, and to develop a simulation tool that will use current facility information to assist in the decision-making process.

References
Adams, T.M. and Smith, J. (2005), “Maintenance quality assurance – synthesis of measures”, Project 06-01, Midwest Regional University Transportation Center, University of Wisconsin, Madison, USA.


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