TOTAL BUILDING PERFORMANCE MANDATES IN BUILDING EVALUATION: A REVIEW

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Abstract
The essence of buildings within the turbulent environment is highly influenced on the efficiency and effectiveness of occupants' performance and comfort. Herein, a re-examination of occupant comfort can offer the impetus for thinking out of the box from general occupant needs to seeking improved quality of life. Creation of user satisfaction can be achieved through the involvement and sophisticated interplay of Total Building Performance Mandates (TBPMs). However, building owners tend to maximise economic gain through the production while ignore the occupant comfort within the built environment. Thus, the aim of this study is to fill the research gap by critically reviewing the relevant literature on TBPMs. A comprehensive literature review was directed to explore the TBPMs (Spatial Performance [SP], Thermal Performance [TP], Indoor Air Quality Performance [AIQP], Acoustic Performance [AP] and Visual Performance [VP]) and acceptable requirements of TBPMs (physiological, psychological, sociological and economic). Further, the paper recognised TBPMs diagnostic measures, indicators and potential health effects. The findings of this study could be used by practitioners as a basis in understanding the BPMs that would be of use in making effective decisions during their endeavours to enhance the total building performance and comfort.

Keywords: *Spatial performance, Thermal performance, Indoor air quality performance, Acoustic performance and Visual performance.*

1. Introduction

In general, buildings are constructed with two main intensions: a precise function, and aesthetic quality. Nonetheless, comfort within the building is one of the undoubted considerations (Celik, 2010). Accordingly, Total Building Performance Mandates (TBPMs) play a dynamic role in delivering comfort to building occupants while achieving building functionality (Lai & Yik, 2009). The term TBPMs is comprised with five mandates namely, Spatial Performance (SP), Thermal Performance (TP), Indoor Air Quality Performance (AIQP), Acoustic Performance (AP) and Visual Performance (VP). These mandates mainly focus on building occupants' requirements and comfort. Moreover, building related pollutions, waste generation and energy wastage can be minimised through proper integration of TBPMs to building design as well as to the building operation (Wang et al., 2010). However, still there appear to be confusions and lack of consideration regarding TBPMs. Hence, this paper is aimed at reviewing the existing literature to identify and explore the concept of TBPMs, five main mandates and considerations of TBPMs to achieve occupants' comfort and satisfaction within the buildings.

2. Research Methodology

A systematic literature review is a vigorous research method that is capable of synthesizing the existing knowledge on the subject, generating new in-sight on a wider scale and recognising novel schemes for future research (Sengers et al., 2019). To accomplish the above mentioned aim of the study, a systematic literature review was utilised. The research methodolo-gy adopted to conduct the systematic literature review is summarised in Figure 1, which is supported by studies of Kilubi (2016).

As illustrated in Figure 1, this study followed seven steps. Intention of step 1 was to formulate specific research focus based on gap identified in the ex-isting knowledge. According to step 2, 'Google scholar', 'Science direct', 'Scopus' and 'Emerald' were used as widely involved domains for conduct review papers (Rathnayake et al., 2020; Fasna & Gunatilake, 2019). Search was conducted for the period from year 2000 to 2020. Through the abstract screening, 48 articles were filtered and finally 32 articles were involved for full text review process. Collected data were analyse using content analysis.

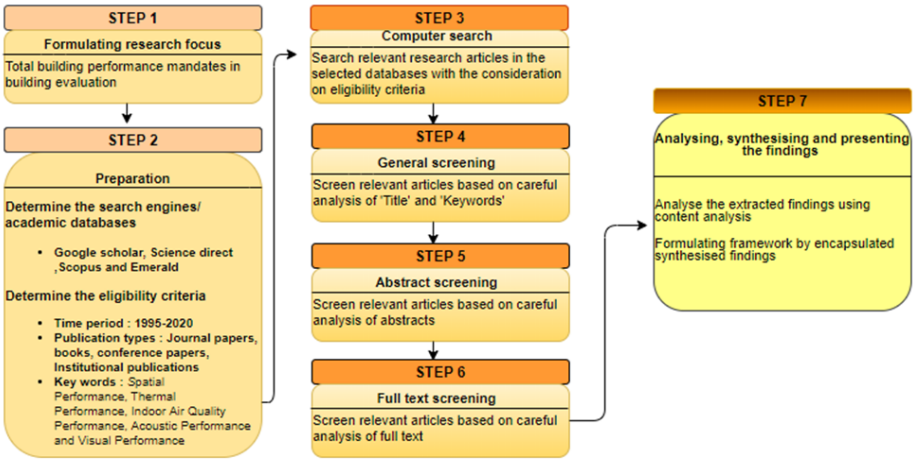

Figure 1, Systematic literature review process

3. Total Building Performance Mandates

Providing comfort to the building occupants is the main essence of a build-ing (Celik, 2010). Therefore, the concept of Total building performance (TBP) was developed within Public Works Canada, Architectural and Building Science Directorate between 1981 and 1985 (Huang et al., 2012). Within the setting of built environment, four conditions should be emphasised for the ultimate success of the application of TBP, namely; occupant satisfaction, organisational flexibility, technological adaptability and environmental, and energy efficiency. TBP can be evaluated and measured through BPMs. According to Celik (2010) BPMs play a vital role in providing comfort to the building occu-pants. Mandates can be described by using two different aspects: funda-mental mandate (refers as building enclosure integrity which protect build-ing's visual, mechanical and physical properties from environmental deg-radation) and series of mandates related to occupancy requirements and comfort (SP, TP, AC, VP and IAQP).

3.1. SPATIAL PERFORMANCE

Spatial performance (SP) concept is known as the functional performance concept in TBPMs (Pheng et al., 2008). In general, main concern of SP is to evaluate ergonomics arrangement of a specific space to gain maximum satisfaction to the respective occupants. According to Magani et al. (2020) spatial arrangement should consider, the work performed, type of furniture and equipment used, the area of storage required and number of occupants. There are main five guidelines which have drafted as main five considerations for SP which involve for display the sign of elevated status. Firstly, achieving ergonomic comfort to fulfil occupants' comfort requirements. Sometimes building designs cannot be fulfilled all the ergonomic requirements of the occupants but theory identifies that ergonomics comfort is to fulfil the greatest possible level of comfort for the greatest number of occupants. Secondly, ensuring privacy. Building occupants do not prefer any disturbances to their privacy, therefore, designers can show the trust by providing enough privacy to the working spaces and this can boost productivity of the occupants (Peng et al., 2020). Thirdly, space conservation. In any workplace, space can identify as a constraint and only limited area available for use. Fourthly, systematic arrangement of space. Available space of the building should be arranged in a systematically, on the other hand, non-systematic space arrangement leads to confusion (Wang & Chiou, 2020). Finally, interaction between users. Space should promote human interactions and should not prevent their communication. Accordingly, walls that use to separate space should not prevent human interaction or should build more avenues to have occupant's interactions with one another (Wang & Chiou, 2020).

3.2. THERMAL PERFORMANCE

The condition of mind which express the satisfaction with the thermal environment is referred as thermal comfort or TP of the building (Huang et al., 2012). TP refers to three components; temperature, relative humidity and air movement (Silva & Ghisi, E, 2020). Further, Frantczak and Wargocki (2011) explained that thermal environment is a combination of four physical variables (air temperature, mean radiant temperature, relative air ve-locity and air humidity) and two variables related to people (clothing and active level). Frequency of the operative temperature (FOT), intensity of thermal discomfort (ITD) and fluctuation of thermal discomfort (FTD) can be pointed out as three indicators for TP of buildings. FOT identifies the most frequent temperatures for a particular building (Sicurella et al., 2012). Further, FOT is useful in comparing operative temperatures with those acquired with other building solutions. Experts have recommended to conduct daily basis analysis for operative temperatures especially when evaluating the movable shading devices. ITD is referred to the difference between current operative temperature and the upper limit of comfort or the lower limit of comfort. ITD parameter is constructed using indoor air temperature, upper limits of temperature and lower limits of temperature. Discomfort in terms of over cooling or over heating can be seen in high ITD situations (Silva & Ghisi, E, 2020). FTD is defined as a way to distinct different situations of frequency of thermal discomfort. Further, FTD can be defined as a ration of the ITD to the length of the period when thermal discomfort is actually occurred (Sicurella et al., 2012).

3.3. INDOOR AIR QUALITY PERFORMANCE

According to United States Environmental Protection Agency's comparative risk studies, indoor air is ranked as one of the top five environmental risks related to public health (Lai et al., 2009). IAQP means air in which there are no known contamination at harmful concentrations and with which a substantial majority (80% or more) of the occupants exposed, do not express dissatisfaction. According to ENV Guide-lines, acceptable concentration of carbon dioxide is 1000 ppm for indoor space (Nazaroff, 2013). Carbon dioxide concentration beyond 600 ppm may cause physiological effect, such as sensation of breathing difficulty, fatigue drowsiness, loss of productivity, absenteeism at work, lack of concentration and sick building syndrome [SBS] (Nazaroff, 2013). In detail, SBS is defines as the condition of at least 20% of the occupants of the building experience symptoms of illness for a period of two weeks or longer, but the source of symptoms cannot be determined.

3.4. ACOUSTIC PERFORMANCE

Acoustic comfort is defined as a state of contentment with acoustic conditions (Wong & Jan, 2003). On the other hand, noise is defined as un-wanted sound that leads to nuisance in the living or working environment (Peters, 2013). Especially this acoustic concept deals with noise and vibration. Unwanted sound which identify by listener can be named as noise and noise is mainly defined on listeners' subjective behaviours. Accordingly, sound enjoyed by one person may be annoying noise in another. AP defers from building's orientation, quality of materials used, workmanship and interior layout of the space. Acoustic measurements can be used for three different purposes, namely, to indicate the effects of exterior noise from neighbouring working stations within the specific building, to indicate the ability of the working station in exterior noise reduction and to indicate the effects of traffic noise on work perform (Wong & Jan, 2003).

3.5. VISUAL PERFORMANCE

VP is defined as a subjective status of visual well-being induced by the visual environment. VP of the building has a direct relationship between com-fort as well as energy consumption of the building. VP is not highly standardised as thermal comfort since it depends on the daylight, screens and glazing that filter the daylight and visual task (Nag, 2019). Luminance distribution, illuminance and its uniformity, glare, colour rending, colour of light, amount of daylight and flick are used to describe the qualities of VP. Illuminance measurements used to evaluate VP and different illuminance levels can be

recognised for different tasks and different functional areas of the building (Nag, 2019). Glare can be identified as a common problem in VP. Daylight is a vital consideration for VP and it is basically assessed through daylight factor (Fasi & Budaiwi, 2015). According to authors, considering only about the daylight factor is not sufficient to evaluate daylight availability for VP. Therefore, due consideration should be given to assess potential natural lighting and shading devices.

4. Diagnostic Measures of TBPMs

TBPMs have their own characteristics, even though they inter-play within the built environment. Therefore, different parameters, tools and techniques are used to evaluate the level of TBPMs in the built environment. Table 1 tabulates the diagnostic measures of TBPMs.

Table 1, Diagnostic measures of BPMs

BPM	Sub parameters	Unit	Tool/ technique
SP	Distance	M or m^2	Measuring tape
TP	Temperature	^oC	Thermometer Humidity & temperature meter
	Relative humidity	%	Humidity & temperature meter Psychrometer or hygrometer
	Average air movement/ velocity	m/s	Anemometer
IAQP	Carbon dioxide level	ppm	CO_2 meter Metrosonic Indoor air quality meter Optical particle counter Condensation particle counter
	Dust level	Mg/m^3	Grimm dust monitor
AP	Ambient noise level	dBA	Sound level meter Acoustic analyser
	Sound intensity (I)	W/m2	
	Sound pressure	Pa	
	Sound power (P)	W	
VP	Lighting level / illuminance	Lux	Light-meter/ lux meter Illumination meter

Source: (Bano & Sehgal, 2019; Kotzias & Pilidis, 2017; Wong & Jan, 2003)

5. Conditions of TBPMs

Four main conditions can be defined as main qualities that should deliver through successful integration of TBPMs to building design (Wong & Jan, 2003). Moreover, these conditions known as benchmarking criteria of five TBPMs. These performance mandates are affected with four conditions of acceptability, namely; physiological, psychological, sociological and economic.

Four conditions directly applied with SP. Physiological conditions deals with ergonomic comfort, safety and health concerns related to SP. Psychological conditions of SP concern about conditions which affects to privacy and distractions (Bano & Sehgal, 2019). Especially, building designers must design by considering disable occupants' needs and wants. Sociological conditions in SP concerns about individuals' needs such as proper communication and interactions (Markoska & Lazarova-Molnar, 2019). Space arrangement should properly facilitate communication needs of occupants and should not stifle the interaction of the occupants. Economic conditions for spatial quality must be covered through proper arrangement of space while maximise benefits to building owner and occupants. Physiological conditions of TP, concern about achieving physical thermal comfort through

engineering and other administrative controls. Providing individual controls for thermal condition and incorporate healthy plants to working environment are some of the examples for fulfilling psychological conditions. Providing comfortable uniform for work is identified as an essential need under sociological aspect. When designing and operation thermal system, energy conservation is a main consideration with the installation of green roofs (Papadopoulos, 2016).

Ensure air purity through proper building envelope design and good ventilation system are considered under physiological conditions of IAQP (Kotzias & Pilidis, 2017). To ensure good mental health of occupants, efficient ventilation and air changes should present. Non-smoking concept is a common and famous initiative under the sociological condition of IAQP. In-corporate energy saving mechanisms to ventilation system is must to fulfil economic needs. To protect occupants from hearing damages, buildings need to be free from excessive noise and working environment need to allow proper communication with speech clarity are examples for physiological conditions (Peters, 2013). Psychological conditions design to support mental health and therefore there should not be excessive noise that could affect building occupants (Wessels & Basten, 2016). Sociological conditions manage well-being of the community within which the occupants act. Economic conditions of AP aim to allocate necessary resources in the most effective and efficient manner to fulfil users' needs within the wider social context (Peters, 2013). Physiological conditions of VP is essential since it may contribute to serious health issues. Integrate cheerfulness, spacious, alive condition, calm and intimate through proper VP are considered under psychological conditions. Selection good quality lighting system whiling managing budget requirements are essential for economic performance of IAQ (Kotzias & Pilidis, 2017). Table 2 explain the summary of building performance man-dates related with four acceptable conditions.

Table 2, Conditions of TBPMs

TBPMs	Physiological conditions	Psychological conditions	Sociological conditions	Economic conditions
SP	• Ergonomic comfort • Handicap access • Functional servicing • Easy access to service systems for maintenance • Distinct space division with appropriate transition	• Privacy for occupants. • Systematic arrangement of space. • Habitability beauty, calm, excitement, view. • Changeable spaces. • Wayfinding through innovative but unambiguous signs	• Interaction of occupants. • Wayfinding • Functional adjacencies. • Easy access to sky garden where could provide private space.	• Cost. • Energy consumption and efficiency • Conversion of materials and other resource. • Space conservation.
TP	• Engineering controls • Administrative controls • No numbness, frostbite, no drowsiness, heat stroke • Measures to reduce heat island effect	• Healthy plants • Sense of warmth • Individual control	• Flexibility to dress with the custom.	• Energy conservation • Green roofs to reduce thermal load and collect rainwater
IAQP	• Appropriate architectural design and elements • Space planning • Ventilation and air change efficiency • Materials selection and specification • Building envelope and openings • Air purity	• Quiet. • Soothing; activity • Excitement 'alive'	• No irritation from neighbours smoke or smells.	• Energy conservation • Separate air ventilation from cooling system which lead to save energy

AP	• External noise minimization • Internal sound minimization • Vibration minimization • Speech clarity. • Music enjoyment	• Appropriate quantity of lighting. • Building envelope and building orientation • Design of openings • Cheerfulness, calm, intimate, spacious, alive	• Internal sound minimization • Building services • disturbance • Vibration minimization. • Privacy and communication.	• Energy conservation

Source: (Kotzias & Pilidis, 2017; Papadopoulos; 2016; Markoska & Lazarova-Molnar, 2019; Wong & Jan, 2003)

6. Potential Health Effects and Measures to Improve the Condition of TBPMs

People spend around 90% of their time in both public and private indoor environments for various building functions whereas, exposure to negative effects caused due to poor attention on the conditions of BPMs (Cincinelli & Martellini, 2017). The health effects of poor performance of BPMs range from short-term effects to long-term effects. Exposure to unacceptable lev-els of pollutants or situations, not only result in health issues but also result dangerous casualties and fatalities. Therefore, potential health effects of BPMs and measures to overcome the identified effects were evaluated as demonstrated in Table 3.

Table 3, Health effects of and measures to improve the condition of TBPMs

TBPMs	Health effects of poor BPMs	Measures to improve BPMs
SP	• Carpal tunnel syndrome • Repetitive stain injury • Ergonomic problems • Musculoskeletal disorders	• Ergonomically arranged work stations with the ability to replacement from sitting to standing positions • Create collaborative spaces, as well as areas to relax and de-stress
TP	• Increased irritability • Loss of concentration • Heat edema • Heat rashes • Heat cramps • Heat stroke	• Use a mechanical ventilation system • Use insulation techniques (cavity walls, loft insulation, internal/ external wall insulation) • Install double or triple-glazing
IAQP	• Watery eyes • Fatigue • Dizziness • Headaches • Upper respiratory congestion • Nasal congestion • Epistaxis • Lung diseases	• Implement 'no-smoking' policy • Develop green cleaning protocol • Install air-filtration • Incorporate healthy office plants • Allow air infiltration • Use non-hazardous chemicals for process
AP	• Hearing impairment • Tinnitus • Heart diseases • Hypertension • Annoyance • Birth defects	• Add additional mass and insulations to wall partitions • Use sound absorbents for suspended ceilings • Use acoustic insulation wall boards • Proper maintenance and fixing of machines
VP	• Eyestrains • Headaches • Neck, back and shoulder strain • Depression	• Measure the average illuminance throughout the workplace and compare with recommended levels • Maximize natural lighting • Correct insufficient light • Mitigate glare issue by using small low-intensity light fixtures rather than one

		large high-intensity light fixtures • Correct contrast issue • Conduct detailed lighting survey

Sources: (Cincinelli & Martellini, 2017; Huang et al., 2012; Wang, 2020; Schibuola, L., & Tambani, 2020)

7. Conclusion

This study elaborated a big picture of the BPMs in building evaluation along with the respective concept illustrations, diagnostic measures, acceptable requirements and potential health effects and measures to improve the condition of BPMs. These five BPMs can be recognised as a series of mandates related to occupancy requirements and comfort. Among the five BPMs, SP knowns as the functional performance mandate and IAQP was revealed as one of the top five environmental risks related to occupant health and well-being. Besides, the paper presents different indicators and diagnostic measures for BPMs that would be useful in maintaining proper conditions in building environment. In addition, a comprehensive list of acceptable requirements for each BPMs that can be integrated as the benchmark criteria were also presented in the study. The findings of this study could facilitate industry practitioners and other researchers to have a better understanding of concepts of BPMs, indicators, diagnostic measures, health effect and measures to improve conditions of BPMs, which would be use for them during their endeavours to enhance building performance of their facilities and further researches. Though through compiling different literature sources, relevant acceptable requirements could be recognised, which is found to be vital in making fruitful decisions regarding BPMs. Hence, assessing TBP that could be gained through proper integration of BPMs found to be a worthy research area.

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