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Influence of Building Characteristics and Building Lifespan on Condominium Operating Expenses

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ABSTRACT

This paper is an exploration of building lifespan, building characteristics, and operating expenses. The main objectives are to identify the building component lifespan, including architectural components and engineering components, to determine the pattern of building component replacement life cycle and to examine the relationship between building characteristics and facility operating expenses. The investigation was undertaken through a study of thirty-nine residential condominiums located in Bangkok. The expense data were collected through document searches and surveys with key juristic persons of each condominium. The building service life document was collected from international references and standards. The data were examined using cross-case analysis to identify the lifespan of the buildings and to identify the relationships between the condominium operating expenses and the characteristics of the buildings. It was found that the typical building replacements occur on a broad 60-year cycle that can be subdivided into several phases. Further findings indicate that a significant pattern of building component replacement shifts every two decades through the building lifespan. It was also found that the condominium operating expenses vary according to the building age and building characteristics. Direct variation, inverse variation, and joint variation from the characteristics of the condominium building can be identified. The findings add to the understanding of condominium operating expenses based on building characteristics. The study can provide a reference for consideration of building selection criteria and replacement plans, and for building budget planning based on age and building characteristics.

Keywords: building lifespan, facility expense, operating expense, condominium,

condominium operating expenses, Bangkok

INTRODUCTION

The lifespan of buildings can be analyzed, understood and explained by identifying the functional components of a building. It is necessary to maintain the condition of each component to meet the standard, both in terms of business aspects and safety factors.

In many countries, reference and standards of building service lifespan have been developed as a preference for practice. The facility manager needs to respond to the specific maintenance conditions of the building component maintenance and replacement in a timely manner. Failure to do so could be a major problem for an aging building. The facility manager is engaged to address and prevent the malfunction of building equipment before the end of its lifespan. So, the facility manager has to convince the building owner(s) that timely renovation and replacement are necessary (Cott & Rondeau, 2004).

The need for building lifespan information has long been widely discussed (Hermans, 1995). However, the studies of building lifespan in Thailand remain few. Furthermore, holistic research about building lifespan is even less prevalent. Gaining further insights into this area will help to improve the involvement of stakeholders related to architectural projects throughout their lifespans. Therefore, studying the facility operating expenses in the case of condominiums should provide insight into how facility managers subsidize facility operating expenses. Furthermore, it will add the study findings of operating expenses and condominium lifespans, both of which have not been fully studied or documented to date.

The lack of information on building lifespan affects the consideration of building operation, maintenance, repair, and replacement planning. These reflect the need for more understanding of the significant operational repair and maintenance related to their lifespans. The specific level of the building components' maintenance needs to be evaluated. This will help establish a realistic budget for maintenance related to the characteristics of any given facility (Stanford, 2010).

The Civil and Commercial Bureau office summarised a statistical report of building permits in Bangkok area in 2017. Residential buildings are the most permitted building type, with 6.75 million square meters or 61.1 percent of the total, while commercial buildings comprise 1.65 million square meters, or 15.03 percent. The amount of permitted area has increased from 2016 by 11.7% in Bangkok. With the increase in permitted residential buildings, higher numbers of condominium stakeholders will face the situation of ownership of an aging building in the long term. The juristic person has to manage the common areas to meet the demands of owners and residents, who are jointly responsible for the costs of maintaining the building and common areas related to each particular unit. This situation will increase the need for proper maintenance planning and budgeting in the future among residential condominiums in Bangkok.

Although the durability of building components and materials should be a crucial issue, it appears to be a negligible issue compare to design criteria, function, and aesthetics (Roberson, 1999). Understanding the life of building components would benefit stakeholders throughout the building lifespan. From the design phase, the architect could add building lifespan as one of the selection criteria in the design of the building. Construction aligned with the design standard, and especial facility management, could be betters understood within the context of the designed life of the building in order to ensure the building performance, the value of the capital investment, and that the structure will last for as long as it should. The mentioned factors give rise to the three main research objectives, as follows:

- To identify the building component lifespan, including architectural components and engineering components
- To determine the pattern of building component replacement life cycle
- To examine the relationship between building characteristics and facility operating expenses

BUILDING LIFESPAN

The building lifespan relies on facility services. A facility manager supervises the building utilisation, facility service, operation and maintenance, budgeting and human resources by understanding the priorities, activities and goals of the organisation. The building is a tool to support organisations in increasing efficiency and effectiveness. The quality of the environment significantly affects users' productivity and performance (Springer, 2004). Identifying the architectural and engineering components of the building is the first step in managing building services. Defining the building operation system requires the analysis of relevant building lifespan factors to achieve the performance goal. There are basic factors that must be considered, consisting of the importance level of operation, type of building usage, and architectural components. The building operation system relies on a number of human resources and various operating models that will be implemented throughout the building's lifespan (Dias, 2013).

Building maintenance activities have different operational objectives and occur at specific times in relation to the age of the building. The operation includes maintenance, repair, and replacement of the building components and equipment (Seeley, 1993). The main goal of the decision-making is to maintain the building in a healthy and safe condition by providing suitable tasks, scope of work, quality of work, and the level of expenses. The key is to provide a facility budget sufficient to deliver building services that meet the required level of quality. The prioritisation of building maintenance of each facility is also based on size, complexity, utilisation of the building. The operations need to improve service performance to align with changing needs through time (Stanford, 2010).

There are many references and standards regarding the age of buildings, but the data sources are to be found separately in many institutions. Building lifespan is a major are of research that has been studied for a long time. As a guide to the building service, it can be used as a reference as well as being part of laws that are enforced in many countries. Building lifespan standards began in 1993, when they were introduced by the Architecture Institute of Japan (1993) which said that the building lifespan prediction should be specified at many levels: in building components, sub-elements, and equipment. The building's expiration is determined by deterioration and physical obsolescence. Determinents of various deterioration rates depend on the building itself, usage, weather, material, quality of the structure, design, construction quality, and level of maintenance (Hermans, 1995). So the age of each building is specific from the application of guidelines for consideration.

In analyzing the differences between the Architecture Institute of Japan (AIJ) and British Standard frameworks for considering the physical age of buildings, it was found that the British Standard BS7543 considers only physical deterioration (British Standards Institution, 1992), unlike the AIJ standard, which covers obsolete buildings and external factors. However, both standards present the building's age according to the design, categorizing them as temporary buildings under 10 years, short-term buildings over 10 years, medium-term buildings over 30, or general buildings over 60 years, without specifying the details of the building or equipment. The designer must realise that the maintainability and replacement of building components has to be a concern during the building design. The Canadian Standard Association presented the Canadian Guideline on durability in 1995, with the addition of knowledge about building modifications. The service life of the building can be considered in light of guidelines for evaluating building performance.

Building component standards are found in laws and regulations as well. The Danish Building Regulations 1995 provide a definition of appropriate building lifespan, and the materials used must be durable and suitable for the purpose. In order to achieve health and safety conditions, The National Building Code of Canada describes the durability characteristics of each element. The building has to have the ability to support the structure efficiently and safely (Canadian Standards Association, 1995).

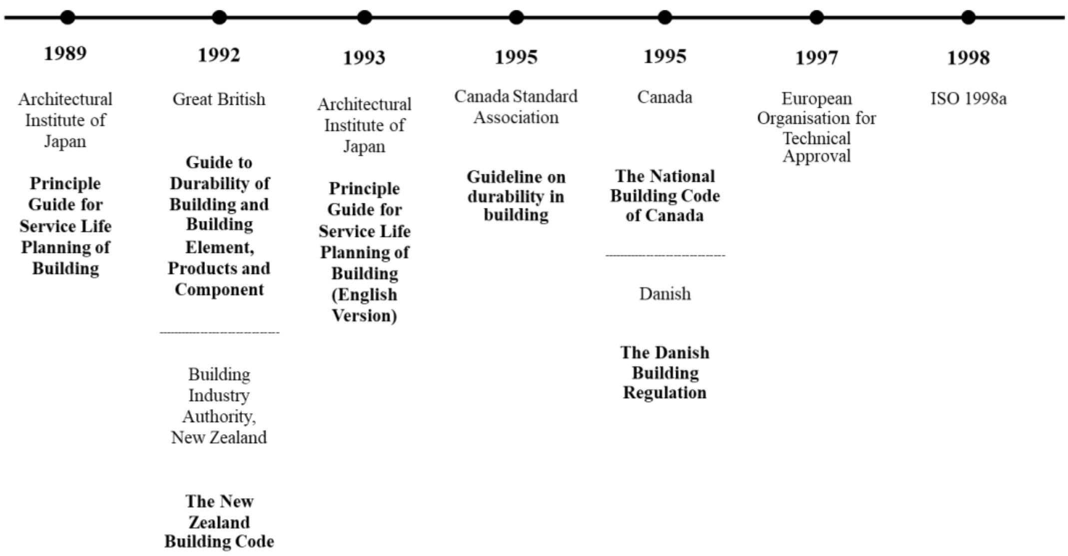
International Organization for Standardization et al. (1997) divided the factors that affect the lifespan into physical condition, environment, and operational characteristics. The physical condition consists of the quality of materials and equipment, level of design and level of operation. The environmental aspect concerns indoor and outdoor visual environments. The operation consists of the operating conditions and the level of service and maintenance.

Housing Association Property Manual Limited (1992) created the HAPM Component Life Manual of the United Kingdom for insuring buildings by relying on age standards from the manufacturer. The United States developed the data further, and created ASTM Standard E1557, ISO Standard 15686-1, Building and Construction Asset Service Life Planning: General Principles, the Canadian Standard Association (CSA), Guideline on Durability in Buildings to forecast building lifespan and Canada Mortgage and Housing Corporation (2003) created Capital Replacement Planning Manual with effective tools for planning and budgeting for capital replacement projects.

In summary, the developement of building component lifespan standards and reference summarized in Figure 1 have beeen developed in many countries. Building lifespan standards are also used as crucial refernce information that contributes to the building of systems to meet the needs, the purpose of use, the ability to maintain the building level as expected, suitable environments, and the ability to respond to usable design by providing proper maintenance so that each component will last for the expected time.

Figure 1

Developement of building service life standards and reference



Note. Development of building service life standards and reference, summarized from literature review.

Factors Affecting Building Lifespan

Architecture and engineering systems cannot always be used as a reference standard. As buildings become older, each one will undergo specific deterioration of each element. Buildings that are continuously maintained according to standards will be able to be used as desired, in accordance with its expected lifespan (Hermans, 1995).

Architectural Institute of Japan, ISO Standard 15686-1 and the Canadian Standard Association point out factors of building lifespan including architecture, area size, height, building shape, construction standards, construction methods, installation, material properties, usage condition, frequency of use, environment, temperature, humidity, quality of design, quality of construction, quality of care, maintenance, management of the building, environment and location. Stanford (2010) analyzed the relationship between standard lifespan and the factors that affect the lifespan, which explain the remaining lifespan and deterioration rate. The considered factors are comprised of service life standards, material quality, quality of design, quality of construction, environment, usage characteristics, and maintenance level.

On the other hand, Herman (1995) describes the componnet lifespan and understanding the the condition level and the amount of deterioration according to usage period combined with maintenance and repair.

The consideration of building lifespan has many aspects. *Physical age* is considered from the permanent strength of buildings and building structures which is a result of the design quality and construction material. The return on investment, according to business objectives, plays an important role in *economic age*. *Utilisation age* refers to the ability to use the facility appropriately to the needs of each activity, while *technology age* accounts for modernity and energy usage values. Laws and regulations should be consider relative to specific changes from goverment. In terms of aesthetics, they are considered in light of changes in design trends (Ashworth, 2010).

The building life cycle encompasses the design, construction, utilisation, and demolition. The building operation (utilisation) period is the longest period. Simultanously, the building undergoes deterioration and obsolescence of architectural components and engineering systems. Achieving a level of quality in building condition requires increased operational expenses when the building is aged (Dhillion, 1989). There are two main approaches for forecasting building lifespan. One of these is to consider the age from factors that affect deterioration; the other way is to focus on the standard of building components. This will cover the uncertainty, in addition to the factors that affect communication in the first direction by relying on data related to damage and operations from the use of the building. Therefore, building life cycle will affect the expenses that are incurred throughout the lifespan of the building.

Facility Operating Expenses

Financial management is a key component of business operations that helps support the business continually to succeed in short and long-term goals. Financial management is needed to meet the organisation's short term, middle term and long term goals (Cott & Rondeau, 2004; Klammt. F, 2004). Owners rely on effective management to create a balance between income and expense. Therefore, financial management is one of the priorities of the organisation that cannot be overlooked (Paramasivan & Subramanian, 2009).

Business operations rely on financial planning as a tool for setting guidelines for operations, coordination, supervision, control, procurement, and use of limited resources. Predicting future expenses involves uncertainty, leading to potential errors. Budget planning and management needs to be carried out with an understanding of the characteristics of expenses, and operating on a regular basis according to a specific time schedule (Langston & Kristensen, 2002). Strategic facility management schemes should align with the needs of the business and the operation model (Chotipanich & Issarasak, 2017).

It is important to clearly identify and understand the actual expenses of the building. A building expenses database can provide the crucial information necessary for forecasting the next annual budget. It also enables the use of data in analysing problems, and considering the efficiency of facility management. With respect to facility management, the facility operating expenses can be divided into four categories: utility expense, facility service expense, repair and maintenance expense, and management and administrative expense.

Understanding the characteristics of facility expense in the long term leads to better long term planning and decision making. The facility manager needs to continually monitor the maintenance activities related to time and characteristics of the facility (Chotipanich, 2010). The category of facility expense outlines a fundamental component of facility operating expenses, shown in Table 1 below. Overall, these facility expenses need to be analysed over the long term.

Table 1

Four facility operation expenses for condominiums concerned with Facility Management

Utility expense	• Related to the use of building infrastructure within the common area of the condominium building.
Facility service expense	• Related to complementary services, or the safety and security of co-owners.
Repair and maintenance expense	• Related to building and engineering system repair, maintenance, and replacement.
Management and administrative	• Related to officer salaries, office stationery and office operating expenses.

Note. Facility operation expenses were identified from literature review.

The need for connecting facility management to the building lifespan has become a key issue concerning aging buildings. It is crucial to identify the model applicable for strategic facility management. One of the effective approaches is to optimise maintenance and replacement activities. Moreover, the building should meet the required performances. The important role of facility managers is in controlling the operational effectiveness through their location, physical environment, space, and services (Beckman & Rosenfield, 2008). The integrated processes within an organisation support its core activities (International Organization for Standardization et al., 1997). User satisfaction and building health are also performance indicators for facility management.

In order to connect facility management and building lifespan, suitable allocation of resources is one of the crucial keys, not only for managing the facility expense, but also replacement expense in the long period of a building's lifespan. Life cycle expenses are not only concerned with the value of money, economic value, and environment impact, but also the value of facilities as well – that is the building lifespan associated with the repair, maintenance, and replacement. Facility life cycle management can provide a decision support tool for ensuring the effective performance of facilities over the long term, involving maintenance and replacement in the future.

CONNECTING CHARACTERISTICS OF CONDOMINIUM BUILDING TO FACILITY OPERATING EXPENSES

Management of any building needs to be considered as a systematic approach of association between building components and various variables. Building age is a forecast of the duration of building and engineering systems. The purpose of the building should be fulfilled in the context of an appropriate environment, durability, strength, and safety (Stanford, 2010). From the literature review, it is found that the data on building life cycle related to actual usage is often lacking for each architectural and engineering component. Study of building age is, therefore, very limited, and assessing accurate life expectancy is difficult. Most of the studies on building lifespan are based on standards as the basis for identifying the age of each building component.

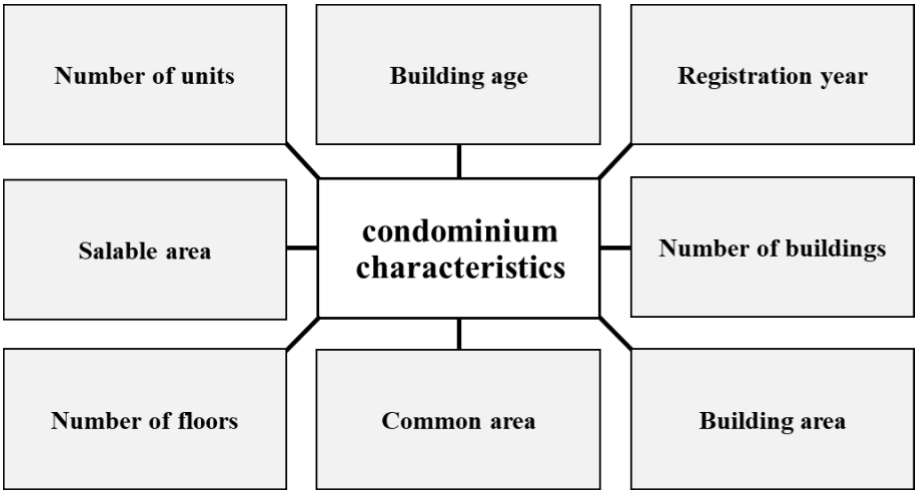
Furthermore, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) is collecting building system service life data of major HVAC systems from practices and various building characteristics. Krstic and Marenjak (2012) decided to collect operation and maintenance expense data and life span data on a university building for a 14-year period.

Ashworth (2010) contributed building cost data related to building components. Raymond and Sterner (2000) identified some of the critical gaps between the theory and practice of life cycle cost. It can, thus, be concluded that there is a research gap, namely, to identify the pattern of operating expenses categorised by building characteristics from the practice. This research aims to relate operating expenses to replacement patterns of building life span.

The building lifespan can be considered in many dimensions for different purposes. It provides information for decision making which will be useful for further investment. Based on the combined results from the various literature, the issues that relate to building characteristics can be grouped into eight major areas – building age, number of units, number of floors, number of buildings, building area, common area, salable area, and year of condominium juristic person registration, as shown in Figure 2.

Figure 2

Variables of building characteristic



Note. Variables of building characteristic were identified from literature review.

Variables That Affect Condominium Operating Expenses

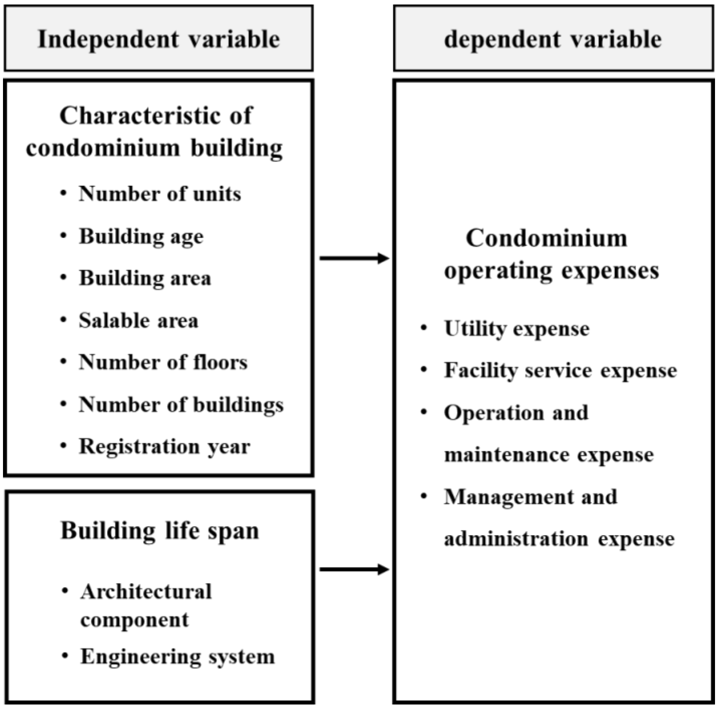
There are various factors affecting building expenses identified from the literature review. In order to anticipate facility operation expenses, the variables are classified into two groups, namely, independent variables and dependent variables. The independent variables include physical factors, such as the age of the building, number of levels, number of buildings, number of units, building area, salable area and common area of the building. The dependent variables refer to expense items that occur each year, consisting of expenses. The total facility expenses are summarised from utility expense, facility services expense, repair and maintenance expense, and management and administrative expense.

In summary, the literature review provided information about the development of building service life standards and references. It also explained the factors affecting building lifespan. Essential operating expenses in facility management planning were identified, as well as the linkage between facility management and building lifespan. The variables of building characteristics that define the relationship between building characteristics and operating expenses were identified, and the approach to facility management and conceptual framework of building lifespan were established.

The building component depends on the characteristics of the building and both architectural and engineering components. The facility manager needs to consider maintenance and replacement reasonably, and ensure the appropiate performance as part of the facility's lifespan. Building lifespan data is a fundamental resource for making critical decisions. In order to understand the nature of facility operating expenses, they need to be monitored and analyzed over time by relating the building chracteristics and component lifespans.

Figure 3

Defining variables in research



Note. Defining variables in research were identified from data on 39 residential condominiums.

METHODOLOGY

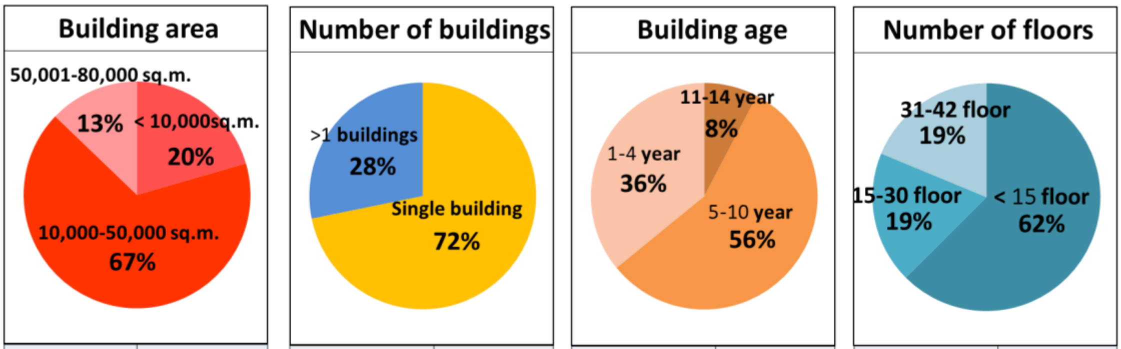
This paper's aim is to gain empirical evidence on condominium facility operating expenses, identify a building component replacement pattern, and understand the relationship between building characteristics and facility operating expenses. By drawing from the available theoretical references and standards through the literature review, this study identified factors of building characteristics and developed a theoretical framework of building lifespan.

There are two main approaches for the data collection. Firstly, secondary data is collected as a reference to identify building component lifespan in each component. In this case, related literature was collected as the reference and standard. This paper is based on the standards from The Building Owners and Managers Association Standard Methods of Measurement (BOMA), The Chartered Institution of Building Services Engineers (SIBSE Guide M), Building Engineering Services Association (BESA), Service and Facilities Group (SFG20), The American Hospital Association (AHA), the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), and The International Association of Certified Home Inspectors (InterNACHI) as a reference of architectural components and engineering components. Secondly, the empirical data are collected from practice. This study undertook the investigation as a case study approach. The selection criterion is set to scope the case study.

This study collected data about 39 residential condominiums located in Bangkok, and registered with the Land Department in Bangkok. Financial information was continuously recorded by the juristic person or entity for each condominium. The case study properties have been managed by only one service provider throughout their lifespans. The expense data are from the annual expense accounts, in which expenses have been recorded. The 39 financial statements from 2018 were collected. The summary of condominium case study characteristics is graphically illustrated in Figure 4.

Figure 4

Summary of condominium case study characteristics

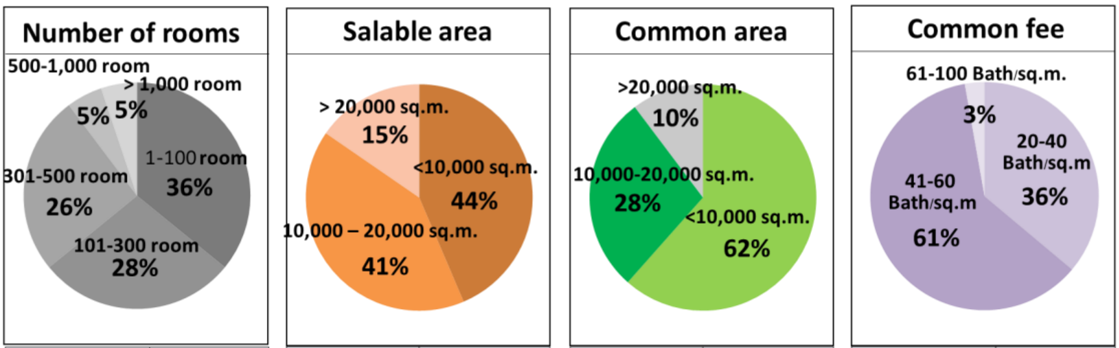


Building area	
Less than 10,000	8
10,000-50,000	26
50,001-80,000	5

Number of buildings	
Single	28
More than 1	11

Building age	
1-4 year	3
5-10 year	22
11-14 year	14

Number of floors	
Less than 15	30
15-30	9
31-45	9



Number of rooms	
1-100 room	14
101-300 room	11
301-500 room	10
501-1,000 room	2
More than 1,000	2

Salable area	
Less than 10,000	17
10,000-20,000	16
More than 20,000	6

Common area	
Less than 10,000	24
10,001-20,000	11
More than 20,000	4

Common fee	
20-40	13
41-60	22
61-100	1

Note. Graphic summary of case study data on 39 residential condominiums.

This paper begins its analysis by comparing each reference standard in cross-case analysis and generating a building lifespan theoretical framework, which provides an overview of the pattern of architectural components and building system component replacement over time. Research framework was identified the building characteristic variable and facility operating expenses. The operating expense data from 2018 were analysed by calculating the average of utility expense, facility services expense, repair and maintenance expenses, and administrative and facility management expenses, which were classified by building characteristics. Finally, this paper analyzes the relationship between building characteristics and facility operating expenses. The operating expenses are divided into 8 categories, namely, building age, number of units, number of floors, number of buildings, building area, common area, salable area, and year of the condominium juristic person registration. In summary, the line chart illustrates the trend of building component replacement each year.

A summary of building lifespan classified by architectural components and engineering systems is provided in an effort to understand and gain insights into building component lifespan. The findings add to the understanding of the condominium operating expense related to building characteristics. This study also discusses the relationship between building lifespan, characteristics of the building, and condominium operating expenses. It also proposes a building lifespan and replacement pattern. The study can provide a reference source for facility managers to use when considering building replacement plans.

FINDINGS

Classification of Architectural Components and Building Engineering System Lifespan

Architectural components and building engineering systems were identified. Six main architectural components and twelve main building engineering systems components were identified from the literature review. Their lifespans were identified and cross case analysis of each building component's lifespan from references and standards was carried out, as shown in Table 2 and Table 3.

Architectural component lifespan includes building structure, walls, floors, ceilings, doors and windows, and roof. In summaryl of the building components shown in Table 2, the lifespan of each is identified by its range, from minimum to maximum. The minimun numbers in the range were selected as the lifespan of component. The structures have the longest life span range; start from 30 years and extends to a century or more. The wall systems range from 15 years up to a century or more, while wall claddings are in a range of 5 to 15 years. The floor systems lifespans vary from 5 to 40 years, whereas the floor finishes have a wider range, from 10 to100 years. Ceilings, doors and windows each have a similar range of approximately 7 to 40 years. The roofs are in the range of 15-50 years. The lifespans of various archtiectural components are related to type of material, so each material should be identified and considered relative to a specific objective.

Table 2

Architectural component lifespan

component	Sub component	type	Lifespan (year)				
			Dell'Isola and Kirk	BOMA	AHA	Inter NACHI	Minimum Lifespan
Building Structure	Foundation	Foundation on ground	40-70	n/a	n/a	n/a	40
	Structure system	Main structure	50-75	n/a	n/a	n/a	50
		Steel structure	n/a	100+	n/a	n/a	100+
		Reinforced concrete	n/a	100+	n/a	n/a	100+
		Wood structure	n/a	100+	n/a	n/a	100+
		Interior wall structure	50-75	n/a	n/a	n/a	50
		Roof deck	50	n/a	n/a	n/a	50
		Roof structure	30-45	n/a	n/a	n/a	30
		Stair structure	40-50	n/a	n/a	n/a	40
Wall	Wall system	Masonry	n/a	100+	40	100+	100+
		aluminum	50	n/a	n/a	n/a	50
		Steel frame	30	50	n/a	n/a	30
		Plywood wall	30	n/a	n/a	20-50	20
		Exposed masonry	75	n/a	n/a	n/a	75
		Drywall	25-35	n/a	15	n/a	25

Table 2 (Continued)

component	Sub component	type	Lifespan (year)				
			Dell'Isola and Kirk	BOMA	AHA	InterNACHI	Minimum Lifespan
	Wall cladding	Gypsum wall	20	n/a	n/a	75	20
		Concrete wall	100+	100+	n/a	75+	75
		Restroom wall partition	20-35	n/a	15	n/a	15
		Stone tile	75	50	n/a	n/a	75
		Ceramic tile	25	n/a	n/a	70+	25
		Exterior wall paint	n/a	5	5	7-10	5
		Interior wall paint	n/a	n/a	n/a	10-15	10
		Wallpaper	n/a	4	5	n/a	4
		Finishing wood	40	15	n/a	n/a	15
Floor	Floor system	Concrete floor	n/a	50	40	50+	40
		Wood floor	n/a	50	n/a	100+	50
	Floor finishing	Carpet	n/a	5	5	8-10	5
		Wood	n/a	10	10	n/a	10
		Laminate	n/a	n/a	n/a	15-25	15
		Epoxy	n/a	10	n/a	n/a	10
		Tile	15-20	n/a	15-20	75-100	15
		Ceramic floor tile	25	n/a	20	n/a	20
		Rubber floor tile	n/a	12	10	25	10
		Granite stone	n/a	75+	n/a	100+	75
		Mable stone floor tile	50	50	n/a	100+	50
		Terrazzo tile	30	n/a	20	n/a	20
		Slate stone	n/a	n/a	n/a	100	100
		Linoleum	n/a	n/a	n/a	25	25
		Stone wash	n/a	n/a	n/a	75+	75
		Concrete	n/a	n/a	20	n/a	20
Ceiling	Ceiling finishing	Exterior Gypsum board	12	n/a	n/a	n/a	12
		Interior Gypsum board	n/a	30	10	40+	10
		Wire mesh ceiling	40	25	n/a	n/a	25
		Acoustic board ceiling	15-20	n/a	8	n/a	8

Table 2 (Continued)

component	Sub component	type	Lifespan (year) Dell'Isola and Kirk	BOMA	AHA	InterNACHI	Minimum Lifespan
		Plaster board ceiling	n/a	n/a	12	n/a	12
		Wood ceiling	n/a	30	n/a	n/a	30
Door and window	Door	Wood door	n/a	n/a	15	n/a	15
		Interior wood door	20-30	n/a	n/a	30-100+	20
		Exterior wood door	30	n/a	n/a	100+	30
		Laminate door	25	n/a	n/a	20-30	20
		Glass	40	n/a	n/a	n/a	40
		Steel door	n/a	n/a	20	n/a	20
		Indoor steel door	30	n/a	n/a	n/a	30
		Outdoor steel door	40	n/a	n/a	n/a	40
		Fixture	n/a	7	n/a	n/a	7
	Window	Wood window	20	n/a	n/a	30+	20
		Aluminum window	30	n/a	n/a	15-20	15
		Exterior aluminum window	35-40	30	n/a	n/a	30
		Glass window	n/a	n/a	n/a	10+	10
Roof	Roof component	Roof tile	15-20	n/a	n/a	20-25	15
		Reinforced concrete roof	50	n/a	n/a	100+	50
		Post tension roof	50	n/a	n/a	n/a	50
		Cement roof tile	n/a	50+	n/a	n/a	50
		Waterproofing coating	40	n/a	n/a	n/a	40
		Metal sheet roof	30	n/a	n/a	40-80	30
		Ridge capping	25-50	n/a	n/a	n/a	25
		Insulation	40-75	n/a	n/a	n/a	40

Note. Architectural component lifespans were collected from *Life Cycle Expenseing for Design Professional,* by Dell' Isola, P.E. and Kirk, S.J., 1981, McGraw-Hill. Copyright 1981 by McGraw-Hill; *Preventive Maintenance Guidebook*: *Best Practices to Maintain Efficient and Sustainable Buildings International*, by Schoen, L.J.P.E., 2010, BOMA International. Copyright 2010 by BOMA International; *Estimated Useful Lives of Depreciable Hospital Assets*, by The American Hospital Association, 2013, AHA Press. Copyright 2013 by The American Hospital Association; and *InterNACHI's Estimated Life*

Expectancy Chart for Florida homes, by International Association of Certified Home Inspectors, 2006 (https://www.nachi.org/life-expectancy.html). Copyright 2006 by The International Association of Certified Home Inspectors.

Building engineering system components comprise electric system, emergency light system, automatic fire alarm system, water system, sanitary system, fire protection system, CCTV, elevation system, lightning protection system, telephone system, and air conditioning system. In summary, electrical system lifespans are in a range of 2 to 40 years. Emergency lighting system have a lifespan of 15 years. The shortest lifespan range among the various systems is the automatic fire alarm system, at 3 to 10 years. Water systems are in a range of 10 to 25 years. Sanitary systems and fire suppression systems are in a similar range of approximately12 to 45 years. Closed-circuit television camera systems, air conditioning systems and elevator systems each have a similar range of 10 to 20 years. Lightning protection systems and telephone systems have lifespans of 25 years and 10 years, respectively. Facility managers should notice the shortest lifespan of the automatic fire alarm, which related to building safety. The number of required replacements in engineering systems starts to escalate progressively from year 10 onward.

Table 3

Building engineering system lifespan

component	sub component	type	Lifespan (year) AHA	ASHRAE	BOMA	CIBSE	SFG-20	Minimum Lifespan
Electric system	Power supply system	Transformer	30	n/a	30	30	n/a	30
		Ring Main Unit	n/a	n/a	40	n/a	n/a	40
		Main Distribution Board	n/a	n/a	30	30	n/a	30
		Load center panel	n/a	n/a	30	15	n/a	15
		Generator	20	n/a	20	25	n/a	20
		Automatic Transfer switch	n/a	n/a	25	n/a	n/a	25
		Power Outlet	10	n/a	n/a	15	15	10
		Switch	10	n/a	n/a	10	10	10
	Lighting system	Indoor fluorescent lamps	n/a	n/a	20	20	n/a	20
		Outdoor fluorescent Lamps	n/a	n/a	n/a	15	n/a	15
		Compact fluorescent Lamps	n/a	n/a	n/a	3	n/a	3
		Fluorescent tubes	n/a	n/a	n/a	2	n/a	2
		Metal halide lamps	n/a	n/a	n/a	3	n/a	3
		SON lamps	n/a	n/a	n/a	4	n/a	4

Table 3 (Continued)

component	sub component	type	Lifespan (year) AHA	ASHRAE	BOMA	CIBSE	SFG-20	Minimum Lifespan
Emergency light system	Emergency light device	Emergency Light	15	n/a	n/a	25	25	15
Automatic Fire alarm system	Automatic Fire alarm device	Fire Alarm Control Panel	10	n/a	15	n/a	n/a	10
		Smoke/Heat Detector	10	n/a	10	10	10	10
		Alarm Bell	10	n/a	10	15	15	10
		Manual Pull Down	10	n/a	10	n/a	n/a	10
		Fire Alarm Battery support	n/a	n/a	5	3	5	3
Water system	Cold Water Pump	Cold Water pump controller	12	n/a	n/a	n/a	n/a	12
		Cold Water pump	15	n/a	15	10	10	10
	Booster Pump	Booster pump controller	12	n/a	n/a	n/a	n/a	12
		Cold Water pump	15	n/a	15	15	15	15
	Cold water pipeline	PVC Cold water pipeline	25	n/a	30	n/a	n/a	25
		Water tank	25	n/a	n/a	35	n/a	25
Sanitary system	Waste water pump	Waste water pump controller	12	n/a	n/a	n/a	n/a	12
		Waste water pump	15	n/a	15	12	12	12
	Rainwater pipeline	Outdoor PVC pipeline	n/a	n/a	n/a	25	n/a	25
		Indoor Cast iron pipe	n/a	n/a	n/a	45	n/a	45
		Underground PVC pipeline	n/a	n/a	n/a	40	n/a	40
		Outdoor cast iron pipe	n/a	n/a	n/a	35	n/a	35
		Indoor PVC pipeline	25	n/a	30	20	n/a	20
Fire protection system	Fire Pump	Fire pump controller	12	n/a	n/a	n/a	n/a	12
		Fire pump	20	n/a	n/a	20	20	20
		Fire engine pump	20	n/a	20	20	20	20

Table 3 (Continued)

component	sub component	type	Lifespan (year)					
			AHA	ASHRAE	BOMA	CIBSE	SFG-20	Minimum Lifespan
	Jockey Pump	Water pump pressure controller	12	n/a	n/a	n/a	n/a	12
		Pressure water pump	n/a	n/a	20	20	20	20
		Fire sprinkle	25	n/a	25	25	25	25
		Hose reel	n/a	n/a	n/a	15	15	15
		Fire Hydrants	n/a	n/a	40	30	30	30
CCTV	CCTV device	Camera	n/a	n/a	30	20	20	20
		Recorder device	n/a	n/a	10	10	10	10
Elevator system	Elevator and device	Life car	20	n/a	20	n/a	n/a	20
		Electric motor	n/a	n/a	n/a	20	n/a	20
		Controller	n/a	n/a	20	n/a	n/a	20
		Governor Rope	n/a	n/a	n/a	10	10	10
Lighting protection system	Lighting protection device	Lightning strike	n/a	n/a	40	25	25	25
Telephone system	Telephone device	Telephone system	10	n/a	n/a	20	20	10
Split Type Air Conditioning system	Split Type Air Conditioning device	Fan coil unit	20	20	20	10	10	10
		Condensing unit	15	20	20	10	10	10
		Insulation	15	20	20	30	n/a	15
		Thermostat	10	16	20	n/a	n/a	10
Central cooling system		Chiller	15	23	20	25	25	15
		Chiller Water Pump	10	20	25	20	20	10
		Condenser Water Pump	10	20	25	20	20	10
	Air Handling Unit	AHU controller	10	15	20	n/a	n/a	10
		AHU	20	20	25	25	25	20
		Duct work	20	30	30	40	40	20
	Fan coil Unit	FCU	20	20	20	15	15	15
		FCU thermostat	10	15	20	n/a	n/a	10

Table 3 (Continued)

component	sub component	type	Lifespan (year) AHA	ASHRAE	BOMA	CIBSE	SFG-20	Minimum Lifespan
	Cooling Tower	Chilled Water Pipe	20	n/a	n/a	n/a	n/a	20
		Chiller condenser Water Pipe	20	n/a	n/a	n/a	n/a	20
		Cooling tower controller	10	16	n/a	n/a	n/a	10
		Cooling tower	20	20	35	30	30	20
		Cooling water pipeline	20	n/a	n/a	n/a	n/a	20
	Exhaust Fan	Exhaust Fan controller	10	16	n/a	n/a	n/a	10
		Exhaust Fan	20	25	25	15	n/a	15
		Chilled Water Pipe	20	n/a	n/a	n/a	n/a	20
		Condenser Water Pipe	20	n/a	n/a	n/a	n/a	20

Note. Engineering system component lifespans were collected from *Estimated Useful Lives of Depreciable Hospital Assets,* by The American Hospital Association, 2013, AHA Press. Copyright 2013 by The American Hospital Association; *ASHRAE Equipment Life Expectancy Chart,* by American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE), 2010 (https://www.formsbank.com/template/116249/ashrae-equipment-life-expectancy-chart-cullum.html). Copyright 2010 by American Society of Heating, Refrigeration, and Air-Conditioning Engineers; *Preventive Maintenance Guidebook*: *Best Practices to Maintain Efficient and Sustainable Buildings International*, by Schoen, L.J.P.E., 2010, BOMA International. Copyright 2010 by BOMA International; *CIBSE Guide M: Maintenance Engineering and Management- A Guide for Designers, Maintainers, Building Owners and Operators, and Facilities Managers,* by Chartered Institution of Building Services Engineers, 2008, Institution of Building Services Engineers. Copyright 2008 by Chartered Institution of Building Services Engineers; *SFG20 The industry standard for building maintenance specifications,* by Building Engineering Services Association, 1990 (https://www.sfg20.co.uk/what-is-sfg20). Copyright 1990 by Building Engineering Services Association.

In summary, the lifespans of building components including both architectural components and building engineering systems were analyzed by comparing various reference standards and identifying the minimum lifespan of each. This section will discuss and highlight key replacement times between architectural components and engineering systems. According to building component life span data shown in Table 2 and Table 3, the architectural components have longer average replacement time than do engineering systems. The average life span of most engineering systems is approximately 10-20 years. The building structure has the longest life span, generally the range of 50-100 years. Lighting systems and fire alarm system batteries require the highest rate of replacement, at approximately 2-5 years. The exterior wall paint, wallpaper, fixtures, carpeting, and acoustic board ceilings require replacement roughly every 4 - 8 years. If the facility manager is not aware of the short term replacement plan, there will be an increasing level of the repair and rising maintenance rate for building components.

The long-term plan over 10 to 20 years should focus primarily on engineering systems; although, with respect to architectural components, the facility management should monitor floors, interior wall paint, partitions, doors and windows with a focus on certain materials, including wood, tiles, laminate, epoxy, ceramic, glass, plastic, steel, rubber, and plywood. In the design phase, architects should consider the life span of architectural components as a crucial part of their specifications.

Classification of Condominium Operating Expenses by Building Characteristics

The analysis evaluates the facility operating expenses in 2018 from 39 residential condominiums in order to understand the relationship between condominium operating expenses and building characteristics. The expenses are divided into 8 categories, namely, building age, number of units, number of floors, number of buildings, building area, common area, salable area, and year of condominium juristic person registration.

The age of the building is divided into 3 groups. It is found that the average expenses of the building during the first 4 years amount to 497 baht / sq.m. / year. When the building is in the range of 5 to 10 years, the average expense is 645 baht / sq.m. / year. When the age of the building is over 10 years, the average expense is 618 baht / sq.m. / year. Therefore, the operating expense tends to rise as the building age increases in 10 years. It will peak when a building is 5 to 10 years old. The average amount of operating expenses is related directly to the age of the building.

The number of units in the studied condominiums ranged from 30 to 1,200 units; they were divided into 4 groups. It was found that the condominiums with range of 30-100 units had the highest expenses, at an average of 727 baht / sq.m. / year. The average expenses for condominiums with 101 to 200 units are 664 baht / sq.m / year, while the average is 503 baht / sq.m. / year for buildings with 201-500 units. For those comprising 501 to 1,400 units, of the average is 419 baht / sq.m. / year. So the expense per square meter tends to decrease as the number of units in the condominium increases.

The number of floors in the studied condominiums is in the range of 8 to 42 floors; they were divided into 3 groups. The results show that the building with 8 floors had average expenses of 698 baht / sq.m. / year while those with 9-30 floors had average expenses of 530 baht / sq.m. / year. However, when the number of floors is greater than 30, the expenses rise to 595 baht / sq.m. / year. Therefore, condominiums with less than 8 floors were found to have the highest expenses per square meter, while the lowest per-square-meter expenses were found in the condominiums with between 9-30 floors.

The number of buildings comprising each condominium project range from 1 to 4; they were divided into 2 groups. Those comprising a single building had an average level of expenses of 654 baht / sq.m. / year. The others had a lower average of 519 baht / sq.m. / year. Overall, the larger the number of buildings, the lower the amount of operating expenses per square meter.

The building area of the studied condominiums ranged from 3,000 to 80,000 sq.m.; they were divided into 3 groups. The buildings comprising 3,000-20,000 sq.m. had average expenses of 722 baht / sq.m. / year. The average expenses dropped to 522 baht / sq.m. / year for buildings comprising 20,001 to 40,000 sq.m., and then dropped even further for buildings comprising more than 40,001 sq.m., which had average expenses of 468 baht / sq.m. / year. It is clear that average expenses per square meter tends to decrease as the building area increases.

The common area of the studied condominiums was in the range of 1,200 to 45,000 sq.m.; they were divided into 3 groups. The buildings with common areas comprising less than 10,000 sq.m. had the highest average expenses, at 681 baht / sq.m. / year. When the building common areas comprised between 10,000-20,000 sq.m., or more than 20,000 sq.m, the average expenses were 535 baht / sq.m. / and 446 baht / sq.m. / year, respectively. Once again, it was found that the expenses per sqare meter tend to decrease when the common area increases.

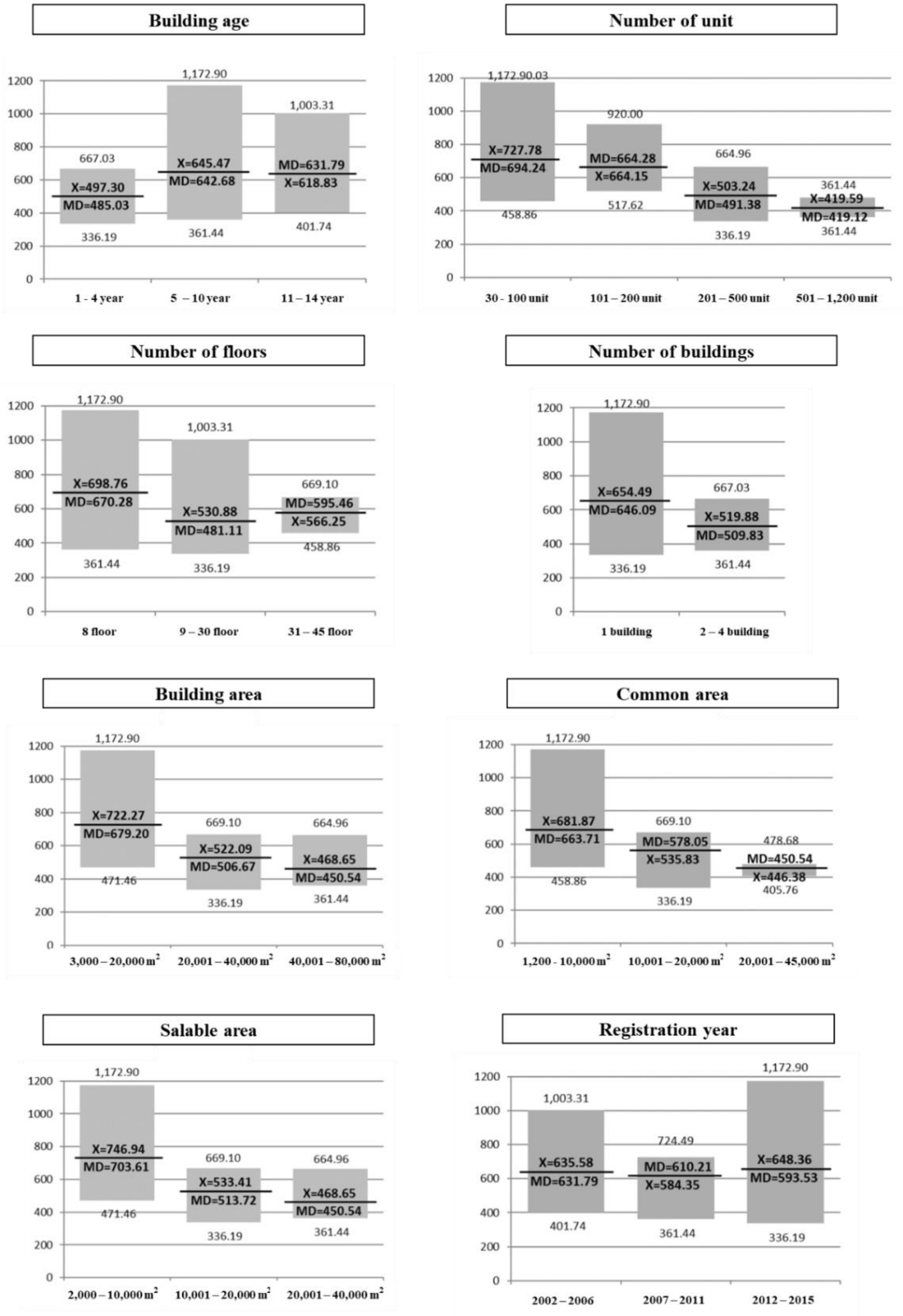
The salable area of the studied condominiums was in the range of 2,000 to 40,000 sq.m.; they were divided into 3 groups: those with salable area of less than or equal to10,000 sq.m., 10,001 to 20,000 sq.m., and above 20,000 sq.m. The average expenses were 746 baht, 533 baht, and 468 baht / sq.m. / year, respectively. Thus, the expenses per square meter tend to decrease when the building area increases.

The condominiums registered year in 2006 to 2011 are divided into 3 groups. The expenses recorded from 2002 to 2006 were, on average, 635 baht / sq.m. / year. The expenses that started recording during the 2007-2011 time period had average expenses of 584 baht / sq.m. / year, and the expenses recorded from2012 to 2015 averaged 648 baht / sq.m. / year. The year in which records began to be recorded was not found to have significant impact on average expenses.

In summary, the operating expenses of condominiums per square meter tend to increase as the building age increases. On the other hand, the operating expense per square meter tends to be lower when the number of units, number of buildings, building area, common area and the salable area are higher. With regard to the number of floors, buildings with between 9 and 30 floors were found to have the lowest average expenses per square meter per year, while those with 8 floors or more than 30 had higher averages.

Figure 5

Condominium operating expense categorised by building characteristics



Note. Condominium operating expenses categorised by building characteristics were analysed from operating expenses of 39 residential condominium in 2018.

Theoretical Framework on Building Lifespan

The theoretical framework was generated from the minimum life span of architectural components and building engineering systems. The number of replacement items each year is summarised in Table 2 and Table 3.

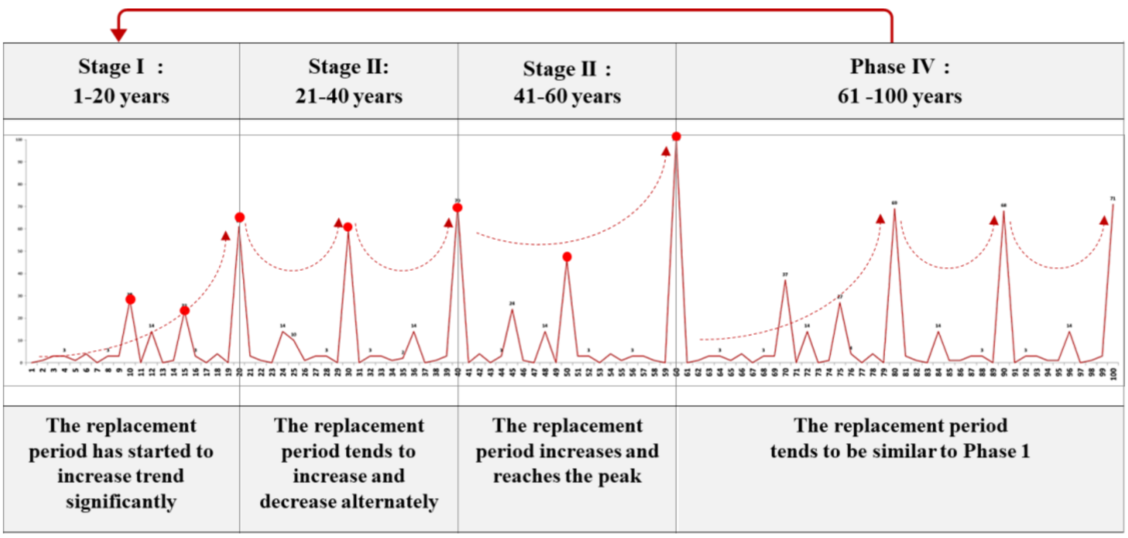
Figure 6 graphically illustrates the pattern of replacements when the information from Tables 2 & 3 are put together to project what happens over the life of a typical condominium building. Based on this graphical information, the conceptual framework of the building lifespan was identified at 60 years.

As can be seen in Figure 6, various elements need to be replaced throughout the life of the building. The graph representing the building life cycle can be divided into 4 clear stages. In Stage I, the replacement pattern tends to peak every 5 years or so until year 20, when it reaches its highest peak. Most equipment will be replaced in Stage II. Building component replacement appear significantly every 20 years. Subsequently, the largest number of replacements will be required at years 20, 30, and 40. The volume of replacement will reach its peak in year 60, which marks the end of stage III. As can be seen in Figure 6, after year 60, the replacement pattern begins to repeat the replacement volumes from the first three stages which defines Stage IV of the building life cycle.

The findings illustrate the relationship between the component lifespans and the graphical presentation demonstrating the pattern of replacement for both architectural components and building engineering systems, which can generate fundamental guidance for predicting the replacement period for each of the building's components.

Figure 6

Theoretical framework on the building lifespan



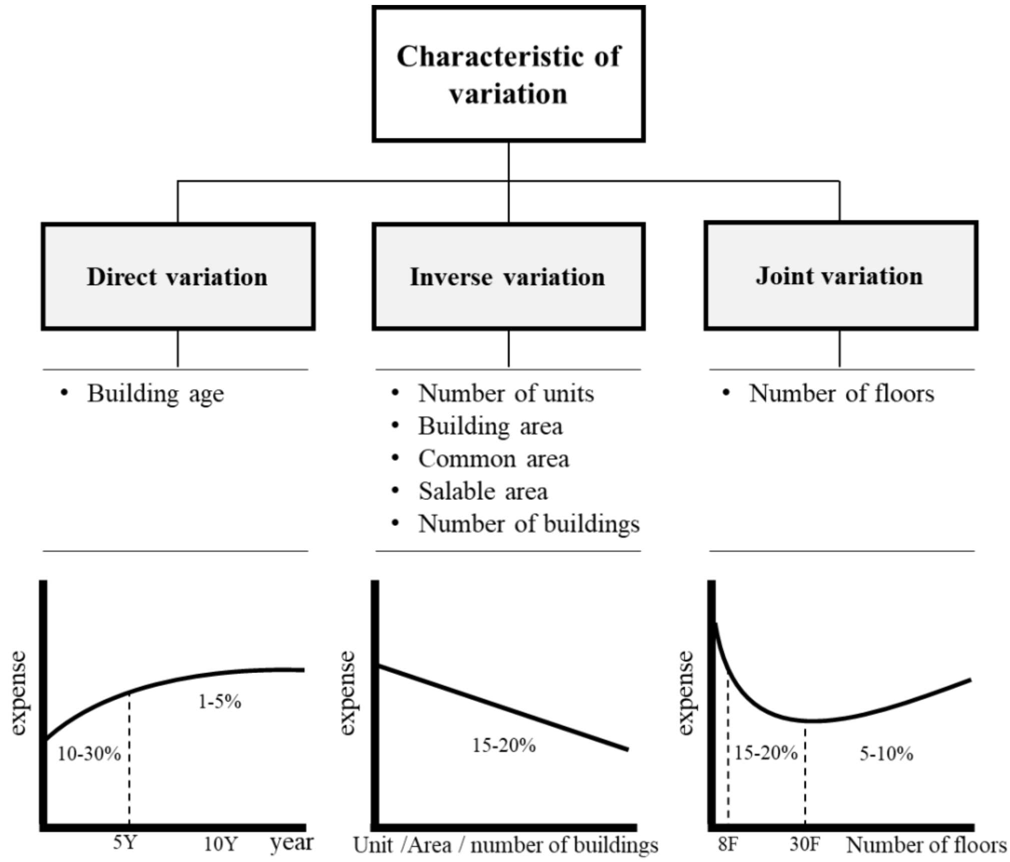
Note. The theoretical framework on the building lifespan was generated from data collection of table 2 and table 3 in this research.

Influence of Building Characteristics and Building Lifespan on Condominium Operating Expenses

The relationship between the characteristics of the condominium building and operating expenses is shown in figure 6. The variables were classified into 3 groups, including direct variables, inverse variables and joint variables. In the first stage, the operating expenses tend to increase 10-30 percent, and, after year 10, without replacement expense included, the expenses rise normally at 5 percent. From the analysis of building lifespan, the facility manager should be aware that the percentage of expenses will rise significantly after 10 years. The relationship between condominium characteristics and operating expenses shows that a variety of components of condominium architecture can combine to reduce operating expenses per square meter by 15-20 percent. By way of example, buildings with 9-30 floors were found to have the lowest average cost; therefore, building characteristics affect operating expenses and building characteristics define budgeting for facility operating expenses. The facility manager should consider the significance of building characteristics as part of the overall plan to ensure the performance of the building in order to reach its designed lifespan.

Figure 7

The relationship of building characteristics to facility operating expenses



DISCUSSION

Overall, the building lifespan and replacement planning in this study share the total of condominium operation expenses, namely, utility expense, facility service expense, repair and maintenance expense, and management and administrative expense. The lifespan of the building components was identified based on data collected, and the building life cycle was divided into 4 phases. The replacement life cycle was identified as being approximately sixty years, comprising the first three phases.

In addition, it is also apparent that different building characteristics are likely to result in different facility operating expenses. Based on the analysis of the theoretical framework on building life cycle and the relationships between facility expenses and building characteristics, a number of points became clear, as follows:

- The building component lifespan was estimated from a variety of architectural components and engineering components found among several reference and guidance sources that were combined to estimate building lifespan, which ranges, generally speaking, from 60 to 100 years. When considering minimum lifespans of building components, architectural components ranged from 4 to more than 100 years, and the engineering systems lifespans were in a range between 2 and 45 years. The framework on the building lifespan reflects the demand for a replacement over time. The component replacement cycle appears to be largely completed at 60 years, at which point, the cycle of replacements begins to repeat.

- The effect of different building components on building lifespans is varied. The theoretical framework on the building lifespan was illustrated based on the data gathered, and it was divided into four phases that were categorized from the theoretical span pattern. The first phase features a rising trend. Replacements appear to plateau in Phase II before reaching the highest frequency in the third phase. In the final phase, the pattern repeats itself, effectively returning to the Phase I replacement pattern.
- The relationships between facility operating expense and building characteristics exhibit a set of operating expenses for each variable. The approach to facility maintenance and replacement planning needs to be adapted to account for these characteristics. In summary, the operating expenses of condominiums per square meter tend to increase as the building ages; however, the average expenses per square meter were found to be lower when the number of units, number of buildings, building area, common area, and the sales area are larger. The average expenses per square meter were found to be lowest in condominiums with between 9 and 30 floors.
- Despite this study focus on condominiums, its results explicitly exhibit the relationship between building characteristics and facility operating expenses. The age of the building seems to be the most significant item among the factors. This study emphasises that facility management needs to be more long-term focused rather than short-term, and that the long term planning has to be connected with timely repair, maintenance, and replacement. This notion from the findings should apply to other types of buildings as well.

CONCLUSION

This paper proposes a building component replacement pattern to gain empirical evidence on condominium facility operating expenses and to understand the relationship between building characteristics and facility operating expenses. By drawing from the available theoretical references and standards through literature review, this study identified a number of variables comprising building characteristics, and developed a theoretical framework of building lifespan. A case study investigation approach was undertaken to investigate thirty-nine cases of residential condominiums located in Bangkok. The average facility operating expenses were examined and analysed. The study illustrates the pattern of building component replacement over time and provides budgeting decision-making guidance with a set of operating expenses related to different building characteristics.

The results of the study show that the building life cycle can be divided into 4 phases, with the replacement cycle lasting approximately sixty years. The proposed model provides a better understanding of building component replacement patterns throughout the lifespan, and allows building characteristics to be correlated with facility operating expenses. It also facilititates the adaption of long-term facility management planning. In addition, it also identifies the relationship between condominium operating expenses and building characteristics by analyzing the average condominium operating expenses from case studies. This finding allows facility managers to consider not only operating expenses related to time, but to consider the characteristics of the building as well. Making decisions on the replacement plan has to be undertaken rationally to align with the building lifespan. Facility managers need to consider the specific building design components that affect lifespan and optimize facility operating expenses related to time and building characteristics.

Although maintenance and replacement activities depend on building material and characteristics, the facility manager needs to continually update the maintenance and replacement plan throughout the building lifespan. By combining the understanding of building lifespan and facility operating expenses, managers can add value by being able to understand and control the overall expenses in both replacement budgeting and operation budgeting.

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