Whole life cost of post offices in Japan, based on a survey of actual conditions and consideration of investment correction

Received (in revised form): 12th February, 2004

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Abstract
A complete enumerative study was made of the operating and maintenance costs of the 1,255 delivery post offices throughout Japan in 2000, in order to grasp the characteristics of the whole life costs of post office buildings. The operating and maintenance cost of five standard post offices were also monitored for 20 years. This paper demonstrates how the acquired knowledge of the whole life costs is used for the decision making of the facility investment. After analysing the relationship between the rebuilding cycle, and rebuilding, repair and improvement costs, by changing the present rebuilding at age 40 to building additions at age 40 and rebuilding at age 60, it became apparent that a significant reduction in facilities investment costs could be expected.

Keywords:
life-cycle cost, rebuilding, life of post office, investment correction repair, improvement

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INTRODUCTION

There is a need to make facilities last longer and reduce upkeep and running costs, reflecting global environmental problems and financial conditions. Although government organisations aim at a long life for their facilities, in view of global environmental problems and expenditure curtailment, there are no stipulated long-

term plans for repair and improvement for public facilities, which are institutionally determined. There is no detailed information about the running costs of most facilities, so it is necessary first to undertake a survey of the present conditions. To apply the results of research on life-cycle cost (LCC) to actual business, in addition to the existing theoretical studies,[1–4] a study is needed on the actual condition of buildings according to their use,[5–8] because there are differences in specifications, operational methods and maintenance methods, depending on the type of building. Few enumerative studies have been conducted on buildings with specified uses. If studies were conducted on a small number of samples, they might not represent the real trend. This paper is based on the results of an enumerative study of Japan's post office building operation costs in a specific year and the results of a monitoring study of five standard post offices over 20 years.[9]

Life-cycle cost

Japan

Since 1991, international conferences involving the departments responsible for post office facilities throughout the world, and particularly from Western nations, have been held, and each country has been developing its own benchmark for their post office buildings.[10] Owing to the differences in structure and specifications of post office buildings from those of ordinary office buildings, it is not meaningful to compare these facilities with other buildings within each country. Therefore, it is considered effective to make a mutual comparison of the post office buildings of countries throughout the world. Each country is aware of the importance of the running costs of these facilities. In Japan, in order to reduce the running costs of facilities and make more accurate investment decisions, when the budget is being put together for new work or extension work, the Ministry of Posts and Telecommunications is presently considering using LCC calculations for reference.[11]

Post office

Benchmark

This paper reports on the results of a study of actual conditions of long-term expenditure required for using LCC in investment decisions. Based on the results of the study, a long-term cash flow forecast of post office buildings is made. The influence on total cost reductions when using the buildings for a longer time is then considered.

FACILITIES SURVEYED

Facilities surveyed

The repair and improvement work costs of all 1,255 delivery post offices owned by the government are covered in this survey (except for the post offices which had moved to temporary facilities in 2000 while being rebuilt), with a total floor space of 6,331,854 square metres. The number of delivery post offices throughout the country by age is shown in Figure 1, and the total floor space by age is shown in Figure 2. Fewer than 40 years have passed since most post office buildings throughout the country were built, and the average age is 23 years. In Japan, mail has been increasing despite the increase in e-mail. An increase in the amount of postage during the period of high economic growth led to a lot of post office rebuilding, centred on the three largest cities, so there are many post offices between 20 and 30 years old.

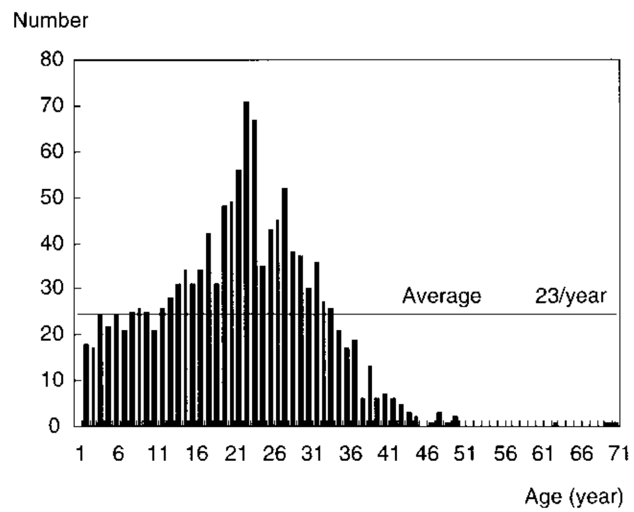

Figure 1: Number of delivery post offices by age (as of 2000)

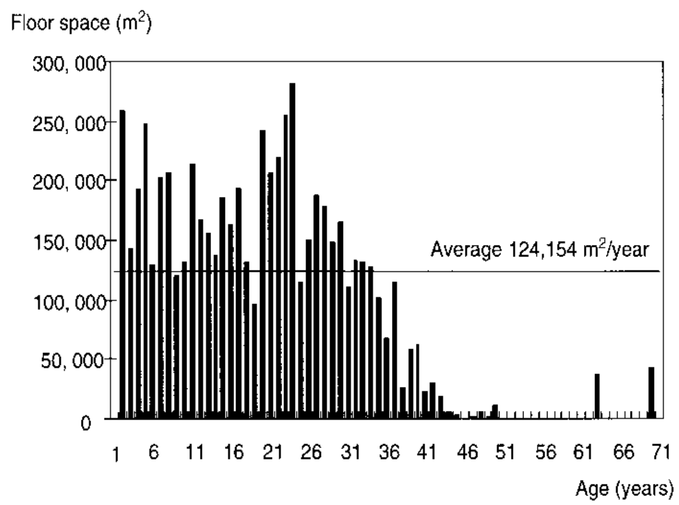

Figure 2: Total floor space by age of general post office buildings (as of 2000)

An outline of the facilities of the five post offices which have been monitored since 1981 is shown in Table 1. The five facilities were the standard post offices of those days.

Repair, improvement, cost

REPAIR AND IMPROVEMENT WORK COST

Relationship between repair and improvement work, and the age of post office buildings

The relationship between the number of repair and improvement works undertaken at 1,255 delivery post offices throughout the

Table 1: Outline of the facilities of five post offices where the LCCs have been monitored since 1981

Post office name	Prefecture	Date built	Structure	Total floor space (m^2)	Site area (m^2)
Odate	Akita	January 1982	RC+2–1	3,872	2,745
Shimozuma	Ibaraki	September 1981	RC+2	1,995	2,629
Kasai	Tokyo	August 1981	RC+2–1	5,508	4,595
Tamagawa	Tokyo	August 1981	RC+2–1	8,538	4,445
Miyakonojo	Miyazaki	March 1982	RC+3–1	5,791	2,667

country in 2000 and their age is shown in Figure 3. There were 15,460 contracts for repair work and 8,185 contracts for improvement work, making a total of 23,645 contracts for repair and improvement works. So far, the repair and improvement work has been carried out as required. The major difference between repair and improvement work is that the former does not include work to improve performance and functions, while the latter improves the performance and functions of the original building, and for budget and accounting purposes, they are handled separately. In reality, however, it is possible that some repair work items are included in improvement work budget orders and vice versa. Therefore, it is appropriate to look at the differentiation of improvement and repair work as a rough estimate. The main content of repair and improvement work includes:

1. repair work required due to dilapidation with age (for example, exterior wall painting, replacement of floor tiles, improvement of arrival and departure doors to load and unload postal matter, and air-conditioner repair work)

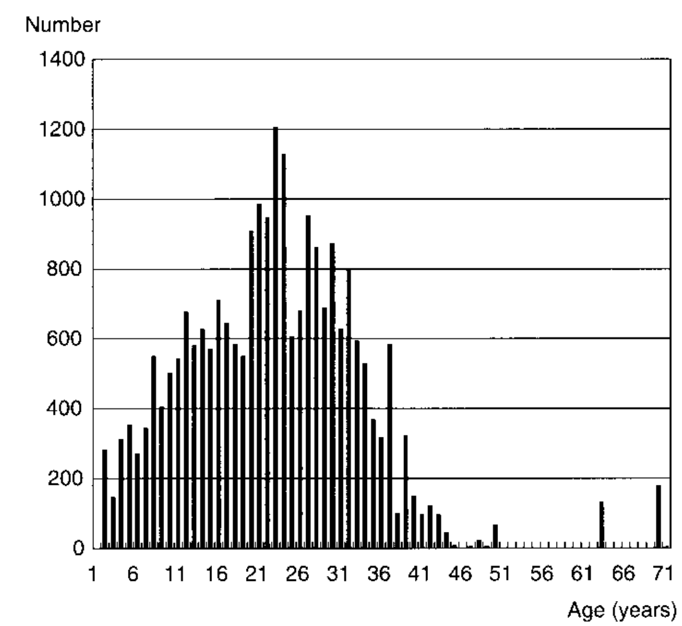

Figure 3: Total number of repair and improvement works by age

2. improvement work for business purposes (for example, installation of passenger and goods elevators, installation of conference rooms and installation of telecommunication equipment rooms)
3. work to improve customer service (for example, expansion and renewal of customer windows and lobbies, and installation of cash service corners).

At 2000 prices, the total repair work cost was ¥3,404,997,856, and the total improvement work cost was ¥23,271,570,681, making a total repair and improvement work cost of ¥26,676,568,537. The total budget divided by total floor space of the post offices in Japan was ¥4,213 per square metre in 2000.

Figure 4 shows the relationship between the total repair and improvement work cost per square metre and the age of the buildings. 'Cost per square metre' refers to the yearly work cost divided by the total floor space in that year. The simple average for the repair and improvement work costs per square metre for only the years when the data are available is ¥4,896 per square metre.

Figure 4 shows that

Tendency

Peak

1. there is a tendency for costs to increase as the buildings get older up to around year 40
2. there is a small peak in years 11 and 23, and a large peak between years 35 and 45
3. even though there are 40 post offices which are being looked at after year 40, the improvement and repair work cost per square metre of these post offices is not exceptionally high.

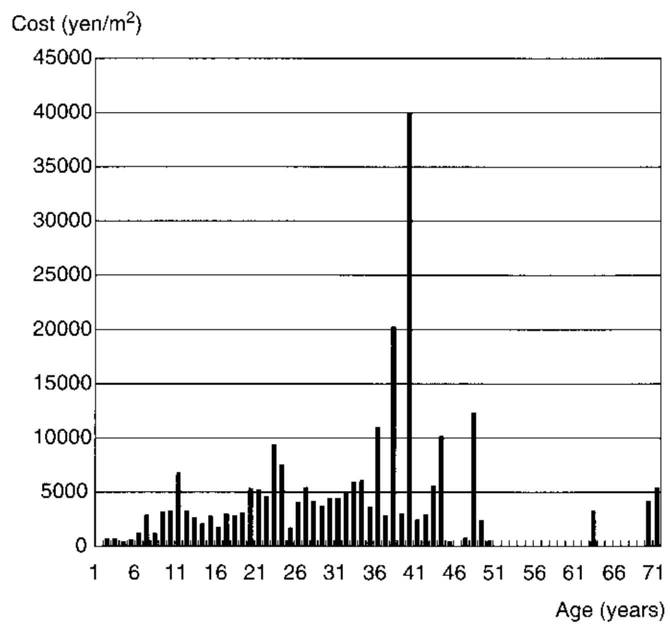

Figure 4: Total cost per square metre for repair and improvement work (2000 figures for 1,255 general sorting post offices)

The peaks for years 11, 23 and 40 shown in Figure 2 correspond mainly to the renewal of equipment and machinery. When updating, it has been the rule to combine equipment and other repair and improvement works intensively to cut down the total amount of construction cost. Even though renewal work is regularly carried out on the customer windows and lobbies, which are the service areas of the post offices, there is almost no conversion: the interior is basically a large working area with little interior finishing. Improvement work is not carried out as much as for private office buildings and, basically, considering corrective maintenance, it can be said that the repair and improvement costs are the minimum essential.

Repair and improvement work in old post office buildings

Rebuild

Up to now, post offices have been rebuilt within 40 years of original construction. There are almost no differences in the specifications of post office buildings which have been used for more than 40 years and those rebuilt in less than 40 years. When there is a need to increase the size of a building to meet increased workload, and it is not possible to expand the size of the original building, the building is newly built at another site. Therefore, the rate of development of the area and the city planning regulations serve as important factors in determining the life of buildings. In 2000, there were 40 general delivery post offices over 40 years old throughout Japan. Except for the eight post offices in areas with slower economic development, most post offices over 40 years old had extension works during the period of high economic growth. In recent years, the age for rebuilding post office buildings is between 30 and 35 years. Large-scale maintenance and modernisation work is also being carried out on buildings between 35 and 40 years old, which are planned to be used continually afterwards without rebuilding.

Extension

Age

There are six post office buildings throughout the country that are 40 years old. One of these, the Kyoto Central Post Office, underwent large-scale maintenance and modernisation work in 2000 (architectural work, ¥840m; electrical equipment work, ¥493.5m; air-conditioning and sanitary equipment work, ¥861m), so the average value for these six post offices is high.

The Kyoto Central Post Office (at present with a total floor space of 43,692 square metres) was completed in January 1971 with a total floor space of 13,723 square metres, had additions of 29,969 square metres made to it 22 years after it was built, in March 1983, along with rearrangement, alteration and conversion of the existing part. Furthermore, 17 years later, in 2000, extensive work was undertaken, including renewal of the air-conditioning system, earthquake resistance improvement, repairs to the interior and exterior walls, installation of additional emergency electrical power generators, improvement of the customer windows and lobby environment, measures for the physically handicapped, heat insulation improvement and roof greening.

Lower cost

The Tokyo Central Post Office was completed in 1931 (total floor space, 42,286 square metres) and the Osaka Central Post Office was completed in 1938 (total floor space, 36,688 square metres). The business overseen by the Tokyo and Osaka Central Post Offices has been moved to new, larger buildings in different locations, so they continue to be used in the style in which they were originally built. Because the Tokyo and Osaka Central Post Office buildings are large, the work cost per unit floor area is small. For efficient office work, several items of repair and improvement work are generally ordered to be done together, but with regard to the Tokyo and Osaka Central Post Offices, most of the work is ordered as it becomes necessary, with an average of one item of work being done each day. This may be influenced by the fact that both these post offices are large organisations with over 1,000 workers, and they are able to handle the ordering of detailed building and repair work. Since there has been no neutralisation of the concrete frame of either of these buildings, it is thought that these buildings were originally built to a high standard and have been maintained with continuous detailed upkeep, which has led to lower repair work costs as the buildings have aged.

Figure 5 shows the proportion of the repair and improvement work costs per square metre for each post office to the average for each year. It is found that the distribution pattern is closest to the logarithmic normal distribution.

Comparison of repair and improvement costs of five monitored post offices with those of surveyed post offices

LCC monitored

Figure 6 shows the changes in total repair and improvement costs per square metre with age for the post offices where LCC havs been monitored since 1981. In 1988, the Ministry of Posts and

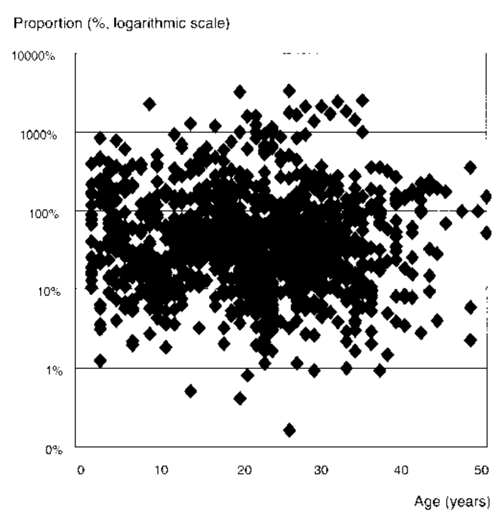

Figure 5: The proportion of the repair and improvement work costs per square metre for each post office to the average of them for each year

Telecommunications began an eight-year plan of renewal work and expansion of customer windows and lobbies of government-owned post offices throughout Japan. The costs are high between 10 and 15 years after completion because renewal work and expansion of customer windows and lobbies was carried out at post offices throughout the country during this period.

Figure 7 shows the cumulative cost of the repair and improvement work per square metre for the 20 years after the facilities' completion. The cumulative total of the repair and improvement work costs (adjusted to 2000 prices) of the five post offices where the LCC has been monitored since 1981 amounts to ¥54,820 per square metre in 20 years (¥2,741 per square metre per year). The total of the average costs for repair and improvement work at the 1,255 post offices since their completion amounts ¥45,560 per square metre in 20 years (¥2,278 per square metre per year). The average costs of the five monitored post offices is 20 per cent higher than that of the 1,255 posts offices over the whole country because the former reflect the costs of the improvement work of the customer windows and lobbies that was conducted when they were 10–15 years old.

Cumulative cost

Figure 8 also shows that the cumulative total for repair and improvement work costs per unit floor space for 1,255 post offices for the 50 years after their completion is about ¥250,000 per square metre. In the fiscal year 2000, no nationwide improvement in facilities was implemented. Therefore, it is thought that the costs

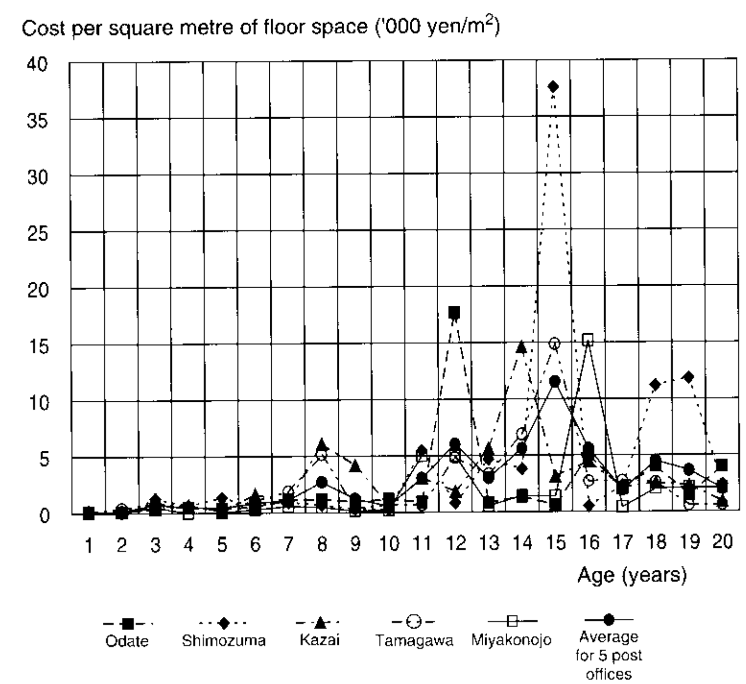

Figure 6: Changes in total repair and improvement costs per square metre with age for the five post offices where the LCCs are being monitored

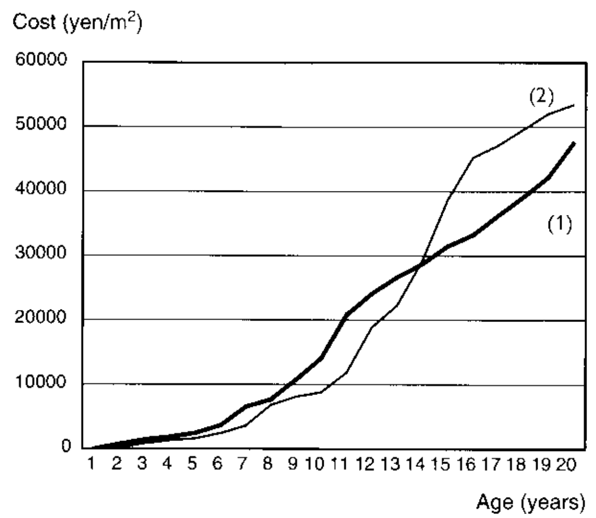

Figure 7: Cumulative total of the average repair and improvement work costs per unit area of 1,255 post offices (1) until buildings are 20 years old; (2) comparison with monitored post offices

which the nationwide investigation shows are equivalent to the minimum necessary repair and improvement costs.

Even though there may be no change in the use of a post office, the facilities need to be improved in order to respond to the demand which was not expected when they were designed. It is always difficult to predict future improvements. The difference between the costs of the five monitored post offices and those in the nationwide survey can be explained by unpredicted improvement work. This difference reflects the change in level of demand for the buildings in the period of investigation, and it may not continue at the same level in the future.

Unpredicted improvement

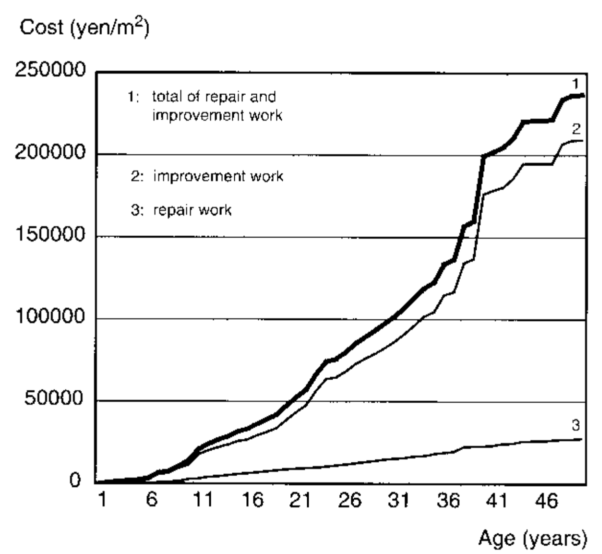

Figure 8: Cumulative total of the average repair and improvement work costs per unit area of 1,255 post offices until buildings are 50 years old

Breakdown of repair and improvement work

Breakdown of repair and improvement work

Figure 9 shows a breakdown by item of repair and improvement work, based on the name of the work ordered. The name of the work is only used to represent the complete content of the work and, generally, most work includes other work not indicated by the name. 'Building' forms 30.1 per cent of the whole.

Sixty-one per cent of 'building' is classified as 'overall building' (Table 2). Figures 10–15 show the relationship between the cost of repair and improvement work and age, by 'architectural' sections such as the roof, exterior walls, exterior fittings, interior ceilings, interior walls, interior floors and interior fittings. The cost of repair and improvement work to the roof increases with time (Figure 10). Usually, a waterproofing sheet is placed over the existing deteriorating asphalt waterproofing in order to reduce the construction cost and time. It seems that the cost of repairs increases as the deterioration spreads with time.

There are three post offices in Japan which are 44 years old. One of these is the Urawanaka Post Office, which has 679 square metres of floor space and had its exterior and interior walls refurbished in 2000, at a cost of approximately ¥37m (Figures 11 and 13). That caused the high cost in the 44th year. It must be remembered that these costs include the costs for other items ordered in addition. Figure 14 shows that the costs for interior floor repair increase with time. The repair and improvement work for exterior fittings occurs at an earlier stage than that for the internal fittings (Figures 12 and 15). The costs for the repair and improvement of exterior fitting are higher than that for interior fittings because they include

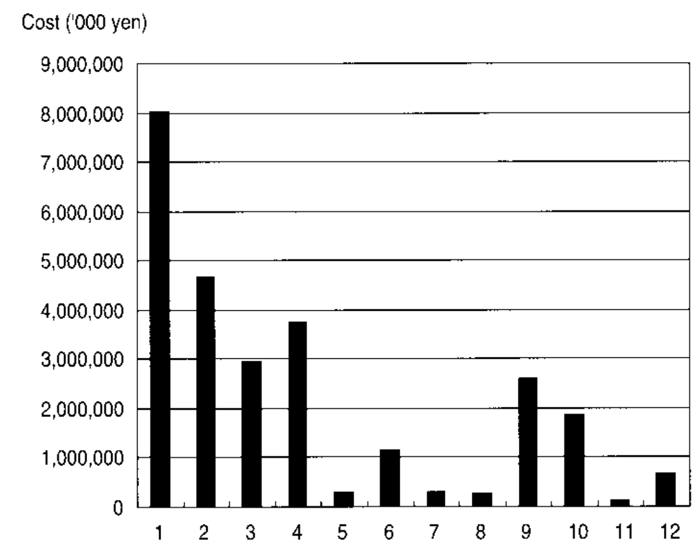

Figure 9: Breakdown of repair and improvement work costs by item
1 Building (30.1%); 2 Electrical (17.5%); 3 Plumbing (11.0%); 4 HVAC (14.0%); 5 Disaster prevention (1.2%); 6 Machinery (4.3%); 7 Customer windows (1.2%); 8 ATMs (1.0%); 9 Sorting machines (9.7%); 10 Earthquake resistance work (7.0%); 11 Barrier-free work for the handicapped (0.5%); 12 Post Office Telecommunications Network (2.6%)

Table 2: Breakdown of 'Building' in Figure 9

Overall building	61.05
Roof	1.99
Exterior wall	11.38
Exterior fittings	5.26
Interior ceiling	0.57
Interior wall	5.50
Interior floor	1.59
Interior fittings	2.19
Others	10.47
Total	100.00

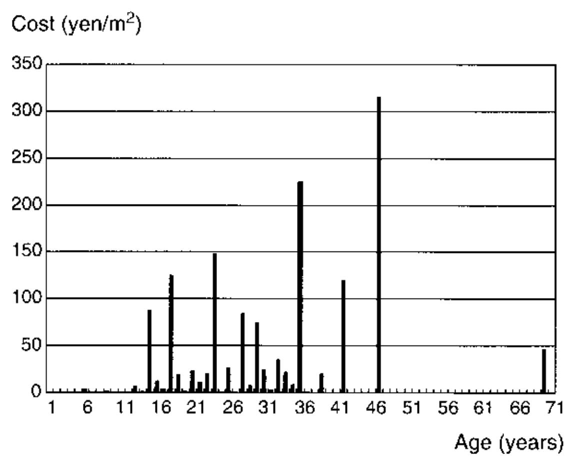

Figure 10: 'Roof' repair and improvement work costs per unit area by age

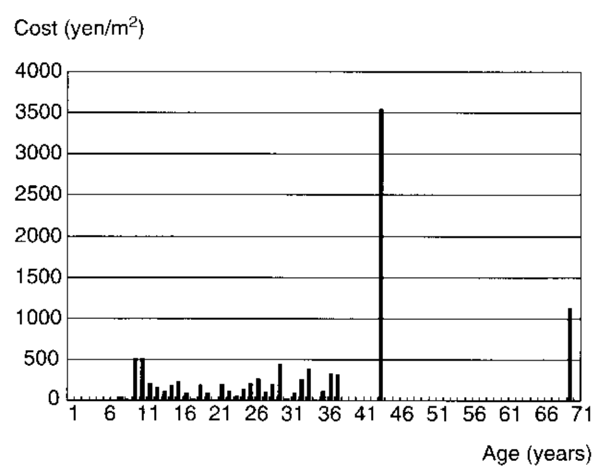

Figure 11: 'Exterior walls' repair and improvement work costs per unit area by age

improvement in the heat insulation of fittings, and also greater deterioration is caused by the severe climate. Since more than 60 per cent of construction work is included in the item 'overall building', the costs shown in Figures 10–15 are not all the costs relevant to each item. Nevertheless, it can be said that these figures

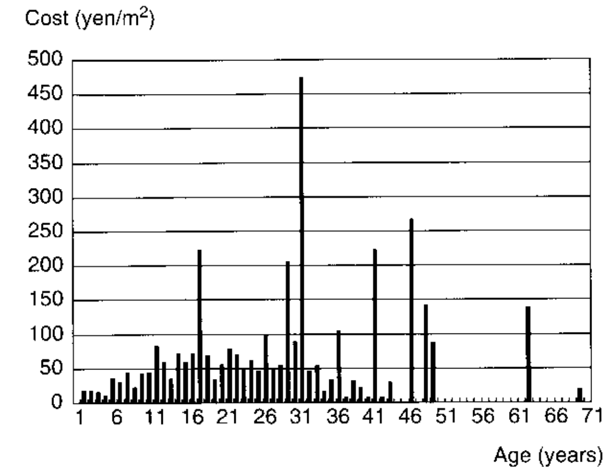

Figure 12: 'Exterior fittings' repair and improvement work costs per unit area by age

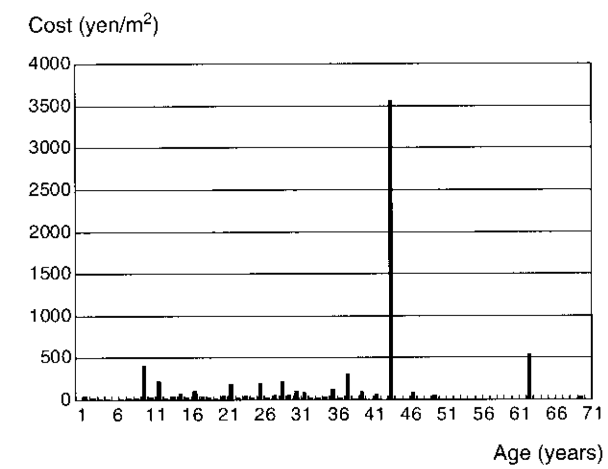

Figure 13: 'Interior walls' repair and improvement work costs per unit area by age

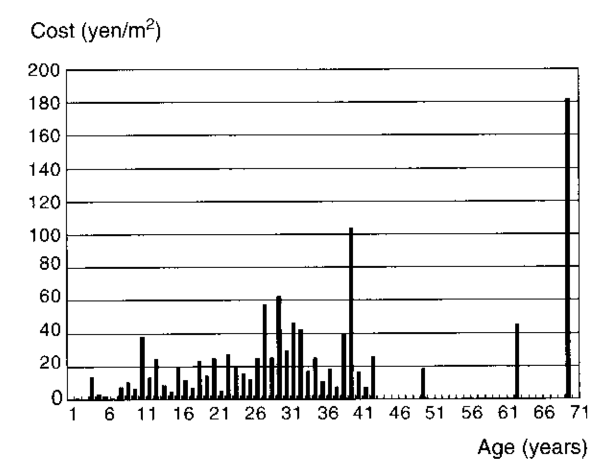

Figure 14: 'Interior floor' repair and improvement work costs per unit area by age

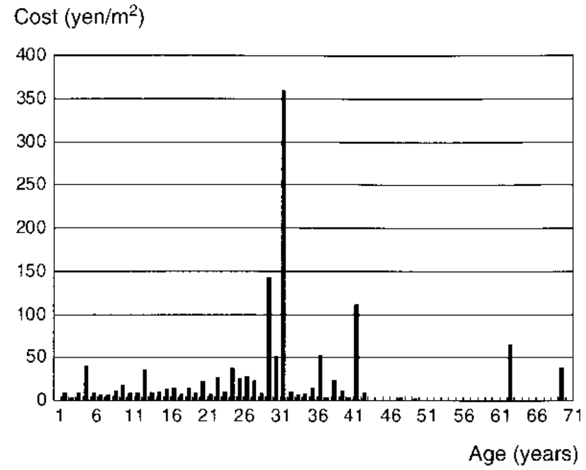

Figure 15: 'Interior fittings' repair and improvement work costs per unit area by age

express the characteristics of the repair and improvement work for each item.

UTILITY COSTS

Electricity, service water, gas

The total electricity cost for the 1,255 post offices throughout the country that were surveyed was ¥15.8bn or ¥2,506 per square metre (2000 prices). The national average costs (and volume) were: ¥329 per square metre (0.85 cubic metres per square metre) for service water and sewerage; ¥241 per square metre (4.86 cubic metres per square metre) for gas; ¥270 per square metre (11.93 yen litres per square metre) for heavy oil; and ¥95 per square metre (4.54 litres per square metre) for kerosene. The total amount for these utility costs was ¥3,441 per square metre (2000 prices).

Figure 16 shows the changes in utility costs per square metre with age for the five post offices where LCC has been monitored since 1981. The common factor for all the post offices is the high proportion of electricity costs.

Because there was a revision in electric power charges due to factors such as gains from the high yen, there was a temporary drop in usage charges. The reason for the escalation in utility costs is because, as the facilities age, there is an increase in the floor space being used, and an increase in the length of time they are being used. There are some rooms in post offices which are only used during the season when New Year's greeting cards are being sorted. Some post offices are sorting 24 hours a day, so a simple comparison of utility costs with facilities with different usage cannot be done.

Linear regression

With regard to utility costs, there is a difference in the amount used, depending on the area. For electricity costs, which account for 70 per cent of the utility costs, when multiple linear regression analysis was carried out using the total floor space, number of workers, the rate of filled vacancy,[12] whether or not there is a

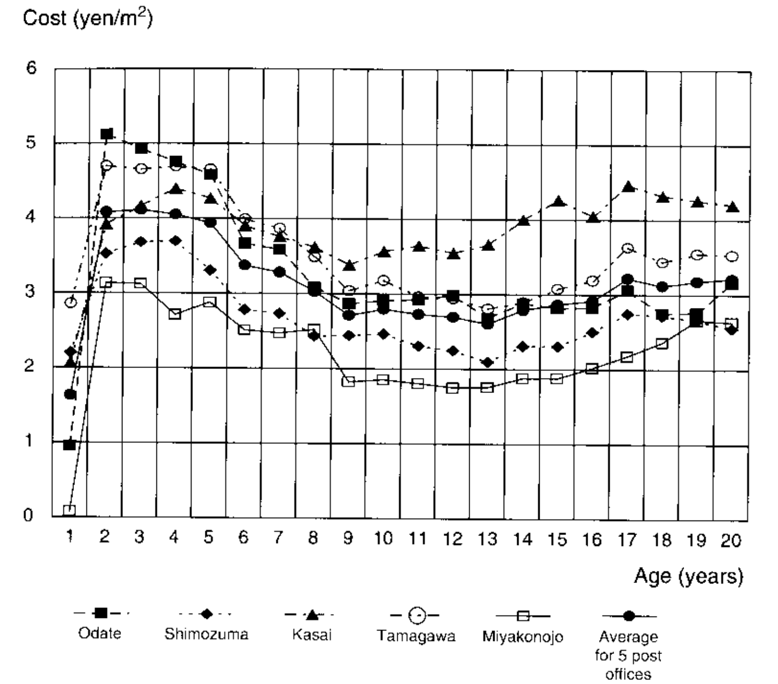

Figure 16: Changes in utility costs per square metre with age for the post offices where the LCCs have been monitored since 1981

cooling tower and climatic areas as the variables, it became apparent that, in each different climatic area, electricity costs had a strong correlation between the total floor space and the rate of filled vacancy. In Area 1 (cold area), electricity costs are low because they do not need air conditioning in summer (Figure 17, Table 3).

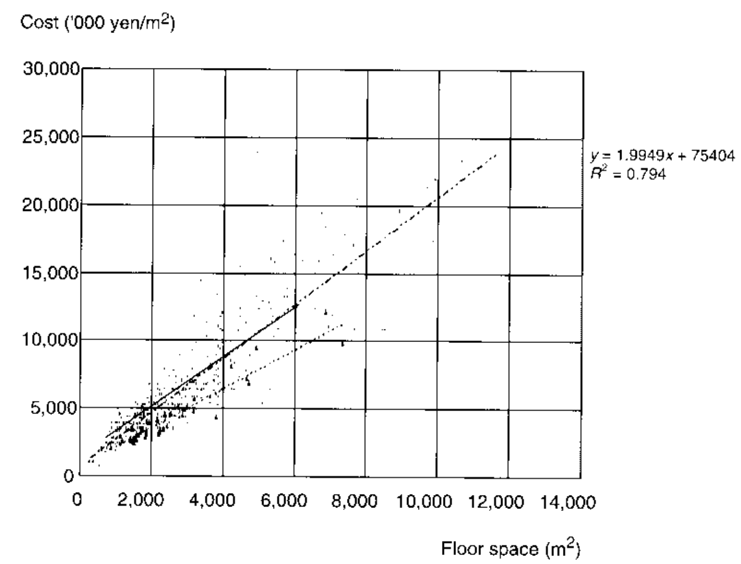

Figure 17: Relationship between the floor space sizes of the post offices and the electricity costs per square metre (Climatic Area 2, 3)

Table 3: Relationship between climatic area and electricity costs

Climatic area*	Correction R^2	No. of measurements	Regression equation	Index
1	0.9763384	73	Y=2272 . X1–70969 . X2+5449047	Y: electricity costs (yen)
2	0.9396989	312	Y=2721 . X1–64461 . X2+3692043	X1: total floor space (m^2)
3	0.9530636	801	Y=3006 . X1–74286 . X2+3952982	X2: rate of filled vacancy (%)
4	0.98083	48	Y=2877 . X1–54125 . X2+2928933	

*The climatic areas are: Climatic Area 1 – Hokkaido; Climatic Area 2 – all the prefectures in the Tohoku region, and Ibaraki, Tochigi, Gunma, Niigata, Nagano, Yamanashi, Toyama, Ishikawa, Gifu, Fukui and Shiga Prefectures; Climatic Area 3 – Tokyo, Chiba, Saitama, Kanagawa Prefectures, all the prefectures in the Tokai, Kinki, Chugoku and Shikoku regions, and Fukuoka, Oita, Saga, Nagasaki and Kumamoto Prefectures; Climatic Area 4 – Miyazaki, Kagoshima and Okinawa Prefectures.
The heat insulation specifications for the post office buildings differ according to the different climatic areas.

MAINTENANCE COSTS

Maintenance costs

The national average maintenance cost for the 1,255 post offices was ¥2,681 per square metre. This broke down into ¥691 per square metre for equipment maintenance, ¥1,448 per square metre for building cleaning and other costs, ¥428 per square metre for security-related costs, and ¥127 per square metre for refuse disposal. With regard to the total maintenance costs, regardless of the age of the post office, about the same costs were incurred nationwide.

Cleaning costs

The changes in maintenance costs with age for the five post offices where LCC has been monitored are shown in Figure 18. Sewage work was completed at the Odate Post Office in 1993, doing away with the need for septic tanks, and leading to a reduction in costs. In 1989, a freight elevator was installed in the Kasai Post Office, leading to an increase in costs.

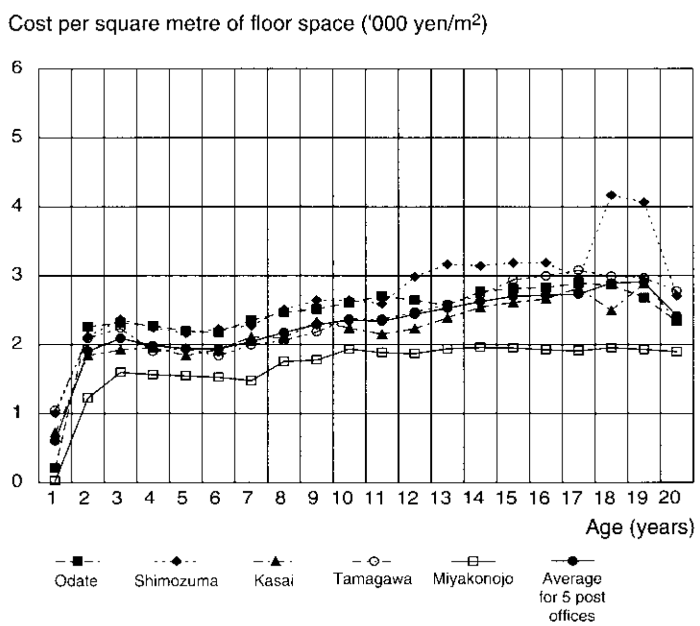

Figure 18: Changes in maintenance costs per square metre with age for the post offices where the LCCs are being monitored

OUTLINE OF THE LIFE-CYCLE CASH FLOW

Life-cycle cash flow

Based on the results of the analysis of the operating costs of the 1,255 general sorting post offices, the life-cycle cash flows for these buildings were calculated for 20, 40 and 60 years (Table 4).

The calculation conditions are:

1. The post office building cost per square metre (*S*) was assumed to be ¥220,000. (There are differences depending on whether or not the post offices have floors below ground, but here the average cost is used.)
2. The average annual repair and improvement work for operating the post office (*C*).
   - *For 20 years*: the cumulative amount of ¥47,451 per square metre (from the actual results for 1,255 post offices; Figure 4) was used.
   - *For 40 years*: for years 1–35, the cumulative amount of ¥122,619 per square metre (from the actual results of 1,255 post offices; Figure 4) was used. For years 36–40, the average value of the actual results of the 1,255 post offices for years after year 41 (¥4,181 per square metre) multiplied by the remaining number of years ($4{,}181 \times 5 =$ ¥20,905 per square metre) was used.

   Reason: The improvement and repair costs per square metre between years 35 and 40 are high, but this is because they reflect repair costs which enable the buildings to be used for over 40 years. Normally, no large investments are made into facilities that are about to be rebuilt. So for the purposes of this analysis, in the case for the model that is to be rebuilt in 40 years, repair and improvement cost for the years after year 36 have been downwardly adjusted.

   Since there are few buildings constructed 50–60 years ago which are still being used, data for this period cannot be obtained. Data can be determined, however, from the results of the facilities which were built 60 or more years ago. The repair and improvement works 50–60 years after completion of Tokyo and Osaka Central Post Offices, which were built more than 60 years ago, correspond more to the changes in society and business than to physical dilapidation. Therefore,

Table 4: Life-cycle cash flow of post office buildings for 20, 40, 60 years (in yen/m^2)

	20 years	40 years	60 years
New building	220,000 (54.0%)	220,000 (35.1%)	220,000 (24.7%)
Repair and improvement	47,451 (11.6%)	143,524 (22.9%)	283,120 (31.9%)
Utilities	68,820 (16.9%)	137,640 (22.0%)	206,460 (23.2%)
Maintenance	53,620 (13.1%)	107,240 (17.1%)	160,860 (18.1%)
Demolition and disposal	17,000 (4.1%)	17,000 (2.7%)	17,000 (1.9%)
Total	406,891 (100%)	625,404 (100%)	887,440 (100%)
EUAC (equivalent uniform annual cost)	20,344/year	15,635/year	14,790/year

it can be said that the cost of repair and improvement work after the physical repair works of the buildings were carried out around 40 years after completion are not so large.

The total of the above (122,619 + 20,905) is used as the improvement and repair cost over 40 years.

- *For 60 years*: the cumulative amount from years 1–40 of ¥199,500 per square metre (from the actual results of 1,255 post offices; Figure 4) was used. For the years after year 40, the average value of the actual results of the 1,255 post offices for years after year 41 (¥4,181 per square metre) multiplied by the remaining number of years ($4,181 \times 20 =$ ¥83,620 per square metre) was used. The total of the above (199,500 + 83,620) is used as the improvement and repair cost over 60 years.

3. With regard to utility costs (E) and maintenance costs (M), no big changes could be seen as the buildings got older, so the average annual cost per square metre was multiplied by the number of years.
4. Demolition and disposal costs (D) were assumed to be ¥17,000 per square metre.
5. Life-cycle cash flow: $LC(n) = S + C + (E + M) \times n + D$.
6. $EUAC$ (equivalent uniform annual cost) $= LC(n)/n$.

Equivalent uniform annual cost

The movement in the total amount of LCC per square metre by age for the five post offices where LCC is monitored is shown in Figure 19. About the same expenditure costs were required between 20 and 25 years after the post offices were constructed as were required

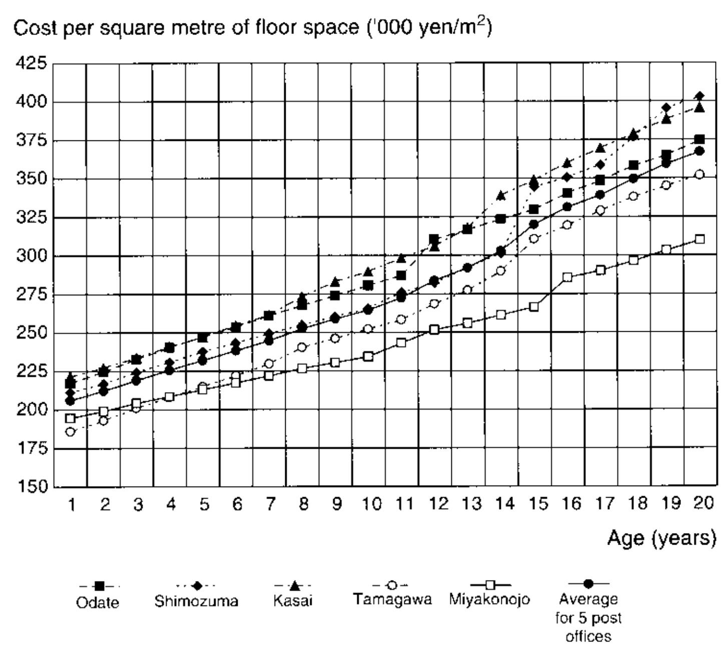

Figure 19: Movement of LCC per square metre by age for the five post offices where the LCCs have been monitored since 1981

when they were first built (after adjustment to present values). After deducting the demolition and disposal costs from the cash flow cumulative total of ¥406,891 per square metre in 20 years, based on the results of the analysis of the 1,255 post offices (Table 4), the figure becomes ¥389,891 per square metre, which is about the same amount as for the five post offices that have been monitored since 1981.

COMPARISON OF FACILITIES IMPROVEMENT AND REBUILDING METHODS USING LCC CALCULATION PROGRAM

LCC calculation program

When post office buildings become too small about 30 years after construction, many questions are asked as to whether rebuilding or improving the existing building and adding to it would be more economical, and to what degree. In order to answer these types of practical questions accurately, the LCC calculation program has been developed. There are various methods of improving existing buildings other than rebuilding, and after analysing the good and bad points of each of these methods, the most suitable method of improvement is selected. Features of this program include the ability to reflect the analytical results of the actual LCC conditions of post offices, and its ability to make calculations for these different facilities improvement scenarios.

Facility improvement scenario

Figure 20 shows one example of the output of the program. At present, 20 years after the completion of the Kasai Post Office, where the LCC is being monitored, the building has already become too small and improvements have become necessary, so the future LCC was calculated for different improvement methods, and comparison studies were made. The amount in year 1 in Figure 20 includes the first year investment amounts for various improvement methods added to the cumulative total amount of the LCC for the 20 years after completion of the Kasai Post Office.

Figure 20 makes LCC simulations for the following five facilities improvement methods.

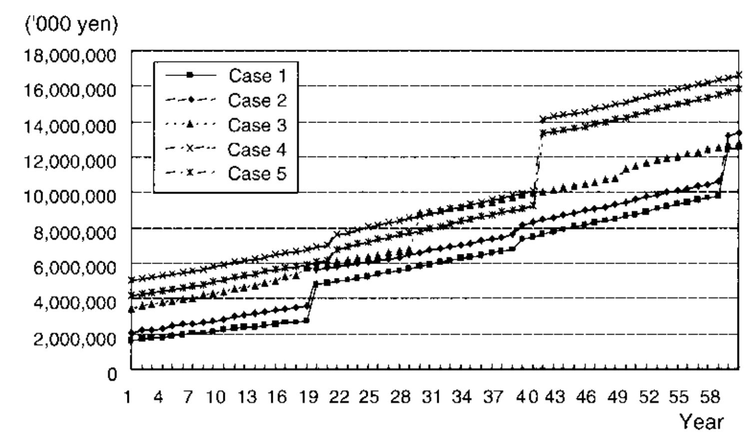

Figure 20: LCC calculations for five case scenarios (example for Kasai Post Office, total floor space 5,511 square metres; fill rate 56%)

Postponement of extensions

– *Case 1*: This time, the equipment and machinery is just renewed (overall maintenance), with extensions to the size of the building postponed. To get around this, some work is moved to another facility, and the present facility is not made any bigger. In 20 years, the building will be rebuilt in a new 11,000 square metre building, and the equipment and machinery will be renewed again in 40 years.

Minimum provisional improvement

– *Case 2*: This proposal is for the minimum required provisional improvements, calling for extensions of 7,297 square metres to be made on top of the existing building (with a rate of filled vacancy of 84 per cent). In 20 years, the building will be rebuilt in a new 11,000 square metre building, and the equipment and machinery will be renewed again in 40 years.

Legal limit

– *Case 3*: This proposal calls for extensions to be made up to the legal limit of the ratio of building volume to lot of 9,044 square metres. (This would temporarily relieve the size problem, and the rate of filled vacancy would be 111 per cent.) In 30 years, the building will be rebuilt in a new 11,000 square metre building, and the equipment and machinery will be renewed again in 50 years.

– *Case 4*: In this proposal, the present building would be demolished, and a new 11,000 square metre building would be constructed (with a rate of filled vacancy of 84 per cent). In 20 years, overall maintenance would be undertaken, and in 40 years, the building would again be rebuilt with the size of 14,000 square metres.

New site

– *Case 5*: This proposal calls for a new site to be purchased, and the facility to be moved to a new building. (Other details are the same as for Case 4.)

The LCC overview is used when making an investment decision to choose whether a building should be rebuilt or continue to be used after improvement and repair work. The post office buildings consist of large working rooms, and if the area is large enough, the ageing of buildings tends not to become a serious functional problem. For old buildings, improvement works such as the insulation of exterior walls and fittings have been carried out, aiming at improvement of energy performance and amenities. With the selection of the facilities improvement method at the budget request stage, first, the level of improvement for the post office functions is considered: not only the facilities-related costs, but all the business costs, including personnel and moving costs, are comparatively estimated. At this stage, a rough cash flow estimate is required. It is imperative that the LCC is used for investment decisions, keeping in mind that it is a pure and simple facilities operational cost-related index.

Discount rate

The discount rate has a major effect on the results of LCC calculations,[13] but because no money is being borrowed when constructing new post offices in Japan, and because no weight is put on the opportunity cost of cost reductions because they are public work projects, a simple cash flow analysis is made, taking into account cost adjustments, but without taking interest payments into account. This is more easily understood by the departments responsible for funding and business management than investment decision indices reflecting the discount rate, such as NPV (net present value).

BUILDING LIFE AND INVESTMENT COST

Post office rebuilding cycle

Rebuilding cycle

Up to now, the floor size of post offices being newly built in Japan has been decided by calculating the required floor space 12 years after the year in which the planning is being done. (Up to 1975, this was based on the required floor space 10 years later, but was changed to 12 years to allow for the period during which land is purchased and planning and construction is carried out.) In calculating the required floor space, a forecast is made of future developments in the area, including population growth, the number of workers, the volume of letters and parcels, the number of delivery areas, the number of delivery vehicles and the number of letter sorting machines.

New post offices are built based on the size required 12 years later, so the size becomes too small 17–20 years later, when additions are made based on requirements a further 12 years later. The size of the land is determined taking into account the size of the building after additions have been made. Forty to 45 years after post offices have been built, they again become too small. At that time, the buildings have generally been constructed as far as the legal ratio of building volume to lot will allow, so if additional adjacent land cannot be purchased, the post office has to be rebuilt at another location.

Serviceable life

Therefore, for planning purposes, the serviceable life for a post office building in Japan used to be about 40 years.

Average age

With regard to post offices that were given budgets for rebuilding work in 1978, the average age for post offices in urban areas was 19.8 years, and for other post offices about 25.0 years. In 1994, the average age of post offices in urban areas was 25.5 years, and for other post offices about 30.3 years. There was a rapid growth in urban areas, centred on the three major cities during the period of

Economic growth

high economic growth and, with the increase in the volume of letters and parcels along with the population growth, there was a need to increase the size of post office buildings. Because post offices suddenly became too small, the buildings were rebuilt within a short period after initial construction. Sudden population growth even in urban areas has settled down in recent years, however, and the time it takes for post offices to become too small has also reduced.

Figure 21 shows the number of general post offices that were given budgets for renewal work in recent years, and the average age

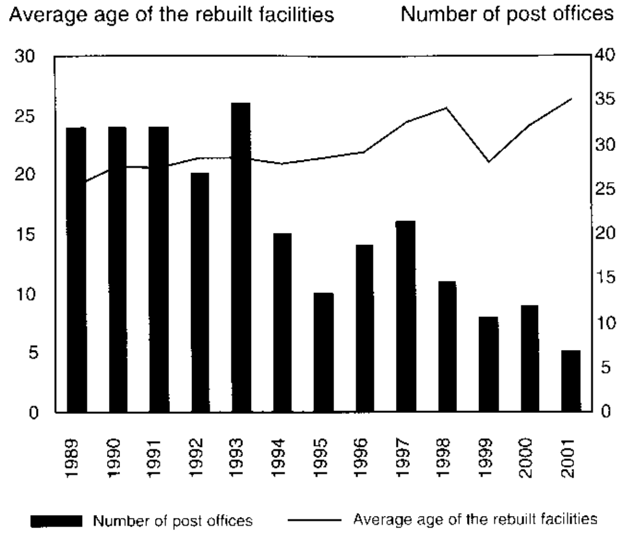

Figure 21: Number of post offices that received budgets for rebuilding (left scale) and the age at which this work was carried out (right scale)

when the work was undertaken. Reflecting the harsh financial situation of the postal business in Japan, there has been a sudden drop in the number of post offices undertaking rebuilding work in the past few years. In addition, the facilities that have become too small are not being rebuilt, but rationalisation measures such as moving certain work to different facilities, consolidating post offices in the surrounding area when one post office is being improved, etc., are carried out, which is also causing a drop in the number of post offices that are being rebuilt. With the drop in the number of post offices that are being rebuilt, there is a gradual increase in the number of years until rebuilding, resulting in rebuilding being carried out nearly 40 years after initial construction, which is about the same as the serviceable life for a post office building for planning purposes.

Lengthening life

Reduction in overall costs by lengthening life of buildings

With global environmental problems, the reduction in industrial waste and the effective use of natural resources in mind, there is a call for increasing the life of buildings and equipment. Increasing the rebuilding cycle of buildings and increasing the number of years they are used reduces the initial investment cost of the overall stock. In general, increasing the number of years a building is used means an increase in repair and improvement work costs, but because the increased amount tends to be less than the reduced initial investment cost, increasing the life of a building is expected to be effective in reducing the overall initial investment and operating costs. The economic feasibility of increasing the rebuilding cycle from 40 to 60 years was analysed by calculating the movement of future construction budgets.

Stock

Economic feasibility

Up to now, post office buildings have been rebuilt in less than 40 years, and the size of the buildings after rebuilding has been about more than twice that of the original. The population of Japan, however, is forecast to peak in 2006, and after that to begin to drop, so no urban growth as was seen during the period of high economic growth is expected.

Therefore, in the calculations, an assumption was made of two models: Case 1 encompassing a 30 per cent increase in the size of the buildings 40 years after initial construction, and a doubling in size 60 years later (Figure 22); and Case 2, in which the buildings are rebuilt twice the size at age 40 (Figure 23).[14] The comparison between the two cases was made in order to find the cost effectiveness of making the rebuilding cycle longer (Table 5).

The calculations consist of:

the rebuilding and expansion work costs in year $n = T(n) \times S$ (where $T(n)$ is the total floor space of the buildings to be rebuilt in year n)
= total floor space in year (40–n) in Figure 1 (for Case 1)
= total floor space in year (60–n) in Figure 1 (for Case 2)

The repair and improvement work costs in year n are

$$\sum_{i=1\ 60} (\text{the total floor space in age } i,\ n \text{ years later}) \times C(i)$$

The result of the comparison reveals that, in Case 2, there is a reduction of ¥1,992.6bn in rebuilding and expansion work costs, looking at the cumulative costs in the next 60 years, and a reduction of ¥31bn in repair and improvement costs, totalling a reduction of ¥2,023.6bn, or an annual reduction of ¥33.7bn (Table 5). The total floor space in 60 years would be 18,009,174 square

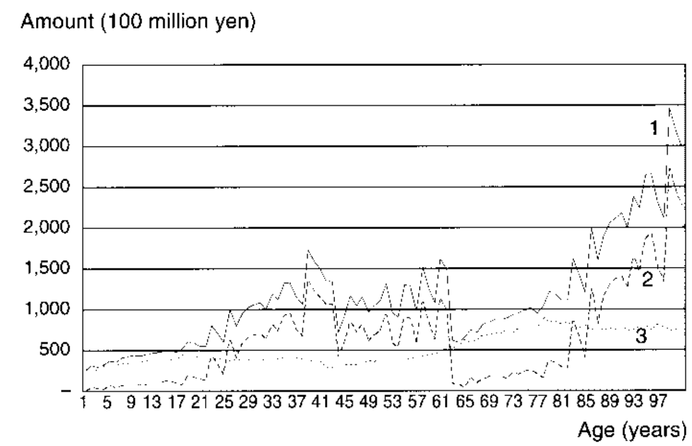

Figure 22: Changes in construction costs over the next 100 years assuming the floor space is increased by 30 per cent at age 40, and the buildings are rebuilt twice the size at age 60

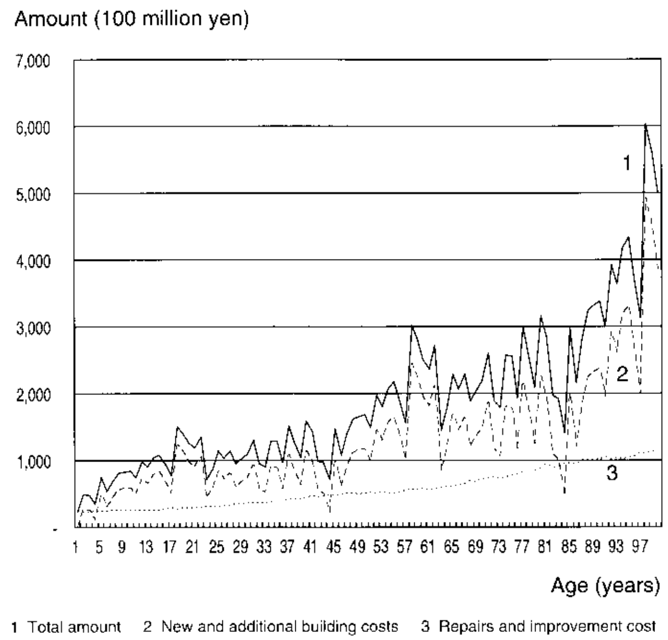

Figure 23: Changes in construction costs over the next 100 years, assuming the buildings are rebuilt twice the size at age 40

metres in Case 1, and 12,590,467 square metres in Case 2. As opposed to an annual average of ¥3,588 per square metre for repair and improvement costs over 40 years, in the case of rebuilding after 60 years, the average is much higher, at ¥4,718 per square metre, but because there is a smaller increase in the total floor space of the facilities, the total repair and improvement costs are lower if rebuilding is done in year 60. If the reduction in cost of ¥33.7bn was divided by the total floor space in 60 years of 12,590,647 square metres, it is ¥2,676 per square metre, which means a large reduction in the annual facility cost.

Reduction

Annual facility cost

In order to reduce facilities investment, in addition to increasing the rebuilding cycle, it is also necessary to control an increase in size. For the Postal Services Agency, which owns a large number of the facilities, in order to undertake the facility investment

Table 5: Facility investment cost estimation for the next 40, 60 and 100 years*

	Case 1			Case 2			Residual of case 2 – case 1		
	R & Exp	R & Imp	Total	R & Exp	R & Imp	Total	R & Exp	R & Imp	Total
AC (40)	27,071	12,181	39,252	15,644	14,668	30,312	−11,427	2,487	−8,941
AVE (40)	677	305	981	391	367	758	−286	62	−224
AC (60)	51,203	22,339	73,542	31,277	22,029	53,306	−19,926	−310	−20,236
AVE (60)	853	372	1,226	521	367	888	−332	−5	−337
AC (100)	130,444	56,859	187,303	63,530	51,365	114,895	−66,913	−5,494	−72,408
AVE (100)	1,304	569	1,873	635	514	1,149	−669	−55	−724

*R&Exp., rebuilding and expansion work costs, R&Imp., repair and improvement work costs; Total, total costs; AC(*n*), cumulative costs in the next *n* years (¥100m); AVE(*n*), average in *n* years (¥100m/year).

Increasing life and controlling growth of facilities

appropriate for the future size of the business, changes in investment policy are required, such as increasing the life and controlling the growth of the facilities.

CONCLUSION

Cash flow

By analysing the actual operating costs of general post offices nationwide, it was possible to make conclusions about cash flow characteristics depending on the life cycle of the post office. The results of the analysis must be understood in light of the fact that post office buildings mainly consist of a large room where postal work is carried out, with little interior finishing and, except for the customer window lobby areas, no large improvement but basically only corrective maintenance is carried out,[15] and with regard to utilities costs, taking into consideration that some post offices continue working throughout the night.

This section makes a general analysis of the tendency of the entire stock, but in reality there are large differences in operating costs between each facility, depending on the building specifications, and how it is being maintained. With regard to the reason for the difference in operating costs, it is important to undertake a detailed analysis at each facility, and work to reduce these operating costs.

The built environment changes over time, seen from physical, social and economical viewpoints. In order to maintain and improve the built environment with limited expense, it must be managed over a long period, by the repair of faults and improvement according to changing demand. For that purpose, it is indispensable to build effective knowledge about what changes will happen to the built environment and how much expense will be required to meet changes that occur.

Data collection

In order to grasp correctly changes in the built environment and the expense accompanying these changes, it is necessary to observe and collect data over a long period. There are only limited data, however, from previous research. The lack of knowledge based on actual surveys causes various problems in managing the built environment over a long period, since a model obtained from limited data analysis has had to be used.

Facility management

Probability of the LCC distribution

This paper has analysed LCC based on an actual survey of post offices owned by the government. Since the data on similar building types and use have been collected over 20 years, the results obtained by the analysis offer useful reference for those involved in facility management. This study shows the maintenance and repair costs will not increase linearly over time, but will stabilise after several decades. Paying attention to the fact that a built environment tends to be influenced by indefinite factors which are difficult to predict, this paper analyses the probability of the LCC distribution. This is a new method of analysis which has not been used in previous research in this field. The author hopes that the results of this paper will contribute to an improvement in the performance of the life-cycle management of the built environment.

Suggested further reading

American Institute of Architects (1977) *Life Cycle Cost Analysis: A Guide for Architects*. Washington, DC, American Institute of Architects.

ASTM E9170-99 *Standard Practice for Measuring Life-Cycle Cost of Building and Building Systems*.

Dell'isola, A. J. and Kirk, S. J. (1981) *Life Cycle Costing for Design Professionals*. New York, McGraw-Hill.

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8. Ishizuka, Y. (1985) 'Second report: The alteration of repair cost about building scale', *Journal of Architecture Planning and Environmental Engineering*, No. 348, p. 53.
9. The Ministry of Posts and Telecommunications has been analysing the following seven categories: (1) Planning costs, (2) New building costs, (3) Repair costs, (4) Improvement costs, (5) Utilities costs, (6) Maintenance costs, (7) Waste disposal costs. All the construction cost prices mentioned in this paper are the common prices adjusted to 2000 fiscal year prices. With regard to planning and design, operation and maintenance costs, the 'Consumer Price Index of Bureau of Statistics, the Ministry of Public Management, Home Affairs, Posts and Telecommunications' is used, and with regard to the new building, repair and improvement costs, the 'Standard Construction Cost Index for Reinforced Concrete Office Buildings in Tokyo by the Construction Industry Business Analysis Committee' is used.
10. The Workplace Network (the Japanese Ministry of Posts and Telecommunications has been participating since 1998).
11. In Norway, when a new post office building is constructed, a life-cycle calculation computer program on the market is used for reference when making the investment decision. In France, the average rate of return, and in Finland, the internal rate of return and the pay back period indices are used when making an investment decision.
12. The rate of filled vacancy is the total floor space at present divided by the floor space required by the building. The size of the building is planned allowing for future requirements, so when the building is completed, the rate is over 100 per cent, and falls as the building ages.
13. Minami, K. (1981) 'Life cycle cost and economic life of buildings', Proceeding of the 52nd Architectural Research Meetings, Kanto Chapter, AIJ.
14. Figures 22 and 23 show investment demand. The actual budgets are standardised for periods of several years. Figures 22 and 23 help in understanding the long-term demand movement.
15. In the near future, the surplus rooms of post office buildings will be converted and rented out.