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LIFETIME AND LIFE CYCLE COST ESTIMATION OF JAPANESE DETACHED HOUSE

KOMATSU, Yukio
Professor, Dept. of Architecture, Waseda University
Ookubo3-4-1, Shinjuku-ku, Tokyo, Japan
Adviser of the House Japan Project
ENDO, Kazuyoshi
Assoc. Professor, School of Architecture, Kogakuin University
Adviser of the House Japan Project

This is an estimation of the life cycle cost (LCC) of Japanese wooden detached houses. At first, the average lifetime of Japanese houses is mentioned. Then as for the study of LCC, we made a questionnaire research, and calculated the survival probability of various part of a house and remaining rate. The years of 50% remaining rate is taken as a standard repair interval to make a simulation model of life cycle refurbishment of a house. The refurbishment cost was estimated from interviews to the professionals or the analysis of real cases. Applying them to the simulation model, LCC of 30 year life is estimated to be 2.16 times of new construction cost, and that of 60 year life is 3.25 times.

1. PURPOSE AND METHOD OF LCC STUDY

Japanese houses have very short life compared to European counterparts. New housing concepts and systems are now being developed to extend lifetime of the Japanese houses and the life cycle cost (LCC) is used to estimate the economical effect of them as an important measure. But the LCC of an ordinary house is not clear yet. In this study, a questionnaire research on the replace/repair interval of housing parts and components was conducted on the detached house owners, and house refurbishment professionals were interviewed to estimate repair/replace cost of various parts of a house. These two researches are jointed to estimate the LCC of a Japanese detached house.

2. LIFETIME ESTIMATION OF JAPANESE HOUSES

Fig.1 shows the expected remaining rate of Japanese houses and the counterpart of U.S.A. This graph is drawn from the result of an analysis called “the periodical remaining rate estimation method” which will be mentioned afterwards. If the expected average lifetime is defined as when the remaining rate reaches at 50%, you can see that of Japanese houses is only 40 years or less. This is almost 40% of the lifetime of the U.S.A. houses, that is almost 100 years.
The reasons why Japanese houses have such short life will be considered in many ways. The main reason I think is caused by the high economic growth of Japan in 1960s to 70s. In this process, Japanese houses’ average floor area was enlarged, and the level of equipments raised so much. This makes older houses out of date, which were built just after the World War 2nd, and the owners of an

old house who got higher income than ever demolished the old house to build a new one. Then the so-called “scrap and build” style was established in Japanese buildings including houses. The environmental problems of the Earth do not allow Japan to continue this style. This situation encourages Japan to develop new housing programs like “SI” or support and infill system.

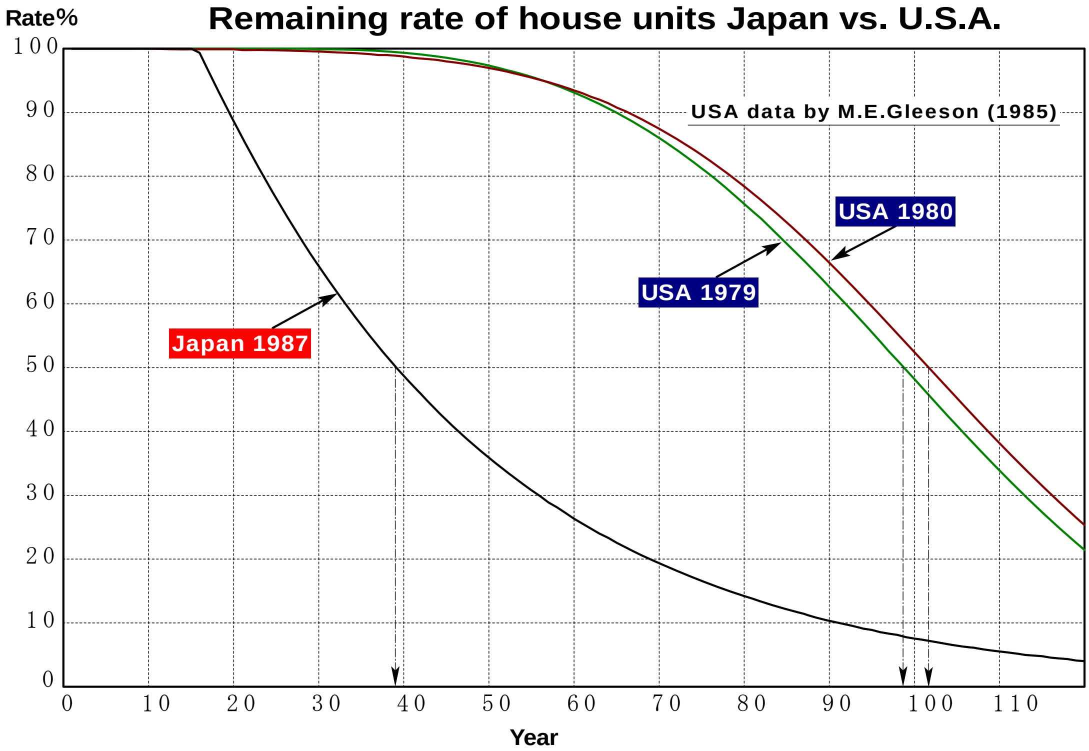

Fig.1 Expected remaining rate of houses

Some past researches and the latest of this kind by Komatsu et al. show that Japanese houses’ average life is elongated recently.

Table-2. Lifetime of wooden detached houses

Year of research	Average lifetime (years)
1997	41.16
1997*	43.53
1990	40.63
1990**	43.61
1987	38.25
1982	37.69

*Tokyo not included. **All over Japan.

Table-3. Lifetime of RC apartment houses

Year of research	Average lifetime (years)
1997	43.44
1997*	43.22
1990	42.51
1990**	43.20
1987	135.86*

*Tokyo not included. **All over Japan.

*** this figure is estimated with small samples so the reliability is not high enough.

3. ESTIMATION OF REPLACE/REPAIR INTERVALS OF HOUSE PARTS/COMPONENTS

3-1. Questionnaire research

The object of this research was to estimate the replace/repair intervals of housing parts and components, such as roof tiles , floor finishes, doors, bath tabs and so on. The questionnaire was conducted on detached house owners, who were the employee of the 38 companies involved in the House Japan Project led by the Ministry of International Trade and Industry. The survey was from June to July of 1996, and 1904 copies of questionnaire papers were distributed where 1553 recovered (the recovery rate 81.6％).

The profile of the houses is as follows: Average floor area is 127.98 m^2, and that of the site area is 228.68 m^2. Years of new construction are shown in fig-2, and you will find that many were built after 1980.

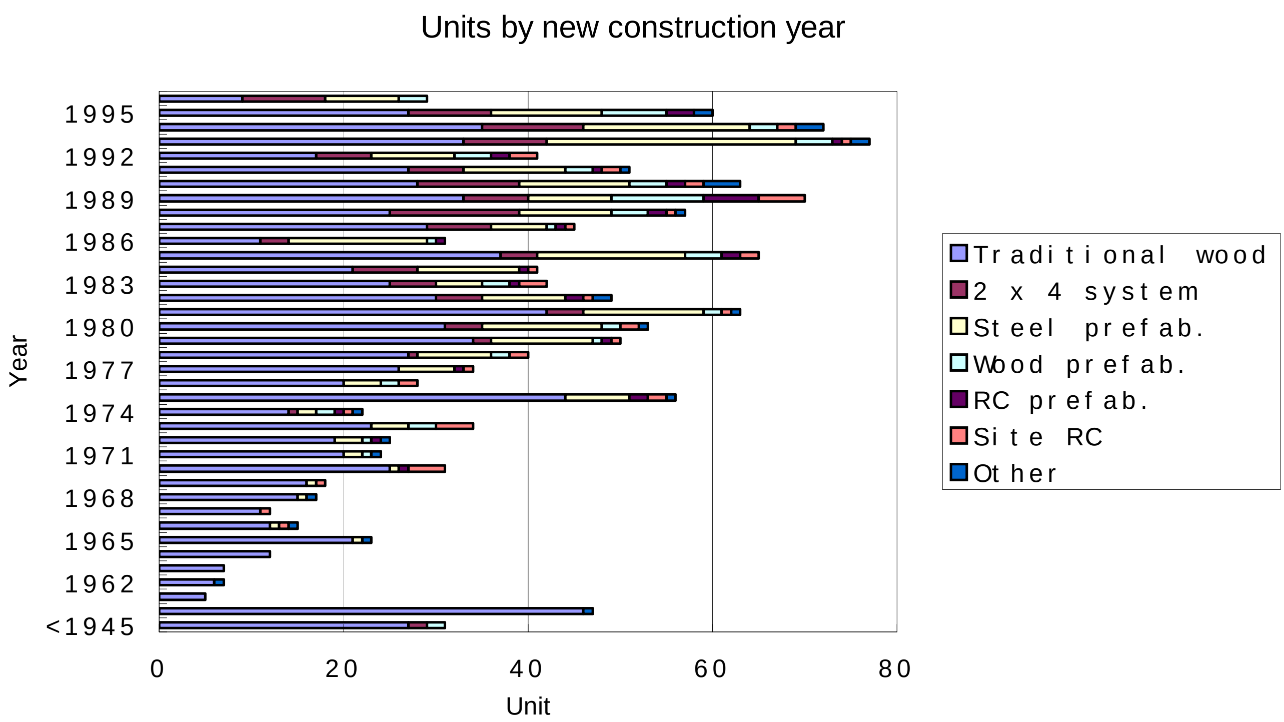

Fig-2. New construction year of the houses of the questionnaire samples

3-2. Items of questionnaire and analyzing method

The items of questionnaire are divided in six large categories, the feature of the house (area, year of construction, materials of finishing materials and so on), reconstruction, repair of the house, addition of equipment, maintenance of the house and the profile of the answerer's family.

3-3. Method of data analysis

From the result of the questionnaire, we estimate the remaining rate of a building part or component. The method adopted here is the one used to estimate the lifetime of buildings, which Komatsu developed and named “the periodical remaining rate estimation method” [Komatsu94] The process of analysis is as follows: First, divide the objects into some groups by age or passed years, then estimate the remaining probability at each age. By multiplying them from smallest age to the largest, we will get the remaining rate figures of the object for the whole life. An example of calculation about Japanese roof tile is shown in table-4.

Table-4. Japanese roof tile replacement

Age	No. of good items	Rate of replace			Remaining	Demolished	Periodical remaining rate	Accumulated remaining rate
		whole	Half	Partial				
2	14	0	0	0	14	0	100.00%	100.00%
3	10	0	0	0	10	0	100.00%	100.00%
4	9	0	0	0	9	0	100.00%	100.00%
5	11	0	0	0	11	0	100.00%	100.00%
6	14	0	0	0	14	0	100.00%	100.00%
7	5	0	0	0	5	0	100.00%	100.00%
8	21	0	0	0	21	0	100.00%	100.00%
9	11	1	0	1	13	1.3	90.00%	90.00%
10	12	0	0	1	13	0.3	97.69%	87.92%
11	9	1	0	3	13	1.9	85.38%	75.07%
12	18	0	0	1	19	0.3	98.42%	73.89%
13	12	0	0	0	12	0	100.00%	73.89%
14	16	0	0	1	17	0.3	98.24%	72.58%
15	17	1	0	2	20	1.6	92.00%	66.78%
16	27	0	0	1	28	0.3	98.93%	66.06%
17	22	2	2	2	28	3.6	87.14%	57.57%
18	16	0	1	1	18	0.8	95.56%	55.01%
19	18	0	0	1	19	0.3	98.42%	54.14%
20	16	0	2	1	19	1.3	93.16%	50.44%
21	10	1	0	1	12	1.3	89.17%	44.97%

The following is the graph of the accumulated remaining rate in roof tiles repair. And the fitted function curve, the Weibull’s distribution is also plotted.

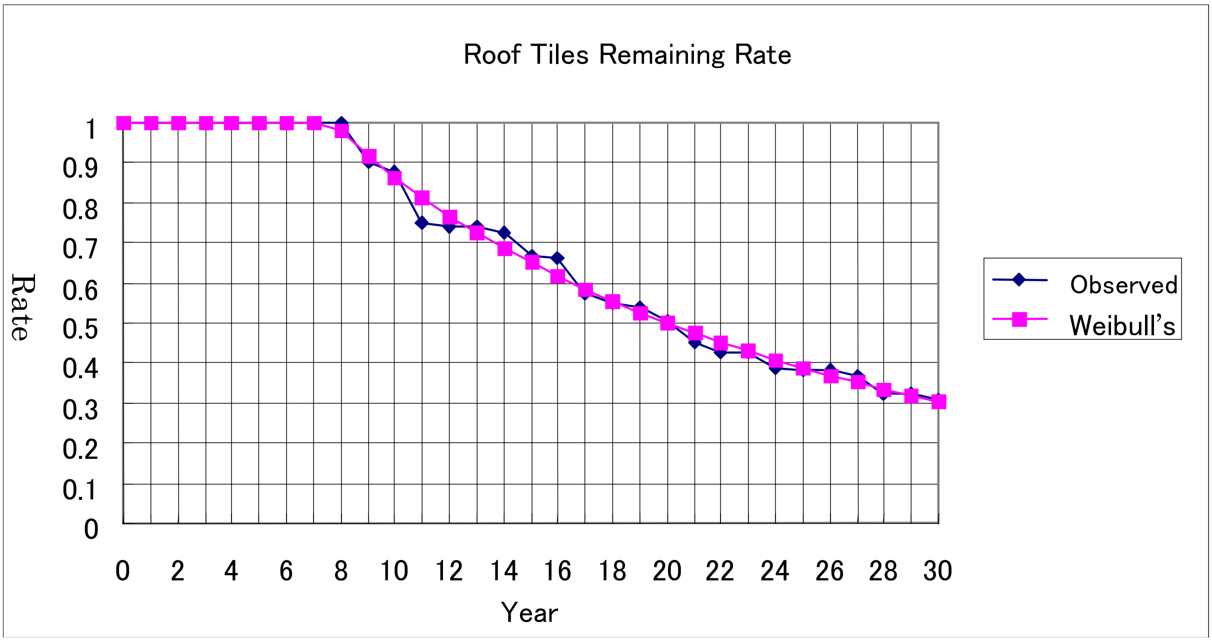

Fig-3. Remaining rate curve of roof tiles

In this study, we decided the average replace/repair interval as the time when remaining rate reaches 50%, then you will find from this analysis that the repair interval is about 20 years. If you think the shorter (or longer) interval is better, you may assume 30% (or 70%) of remaining rate as the criteria.

3-4. Estimation of replace/repair intervals

From a remaining rate estimation mentioned above, we can estimate the replace/repair intervals.

Table-5. Example of replace/repair intervals(year)

Materials	R.R.= 0.7	R.R.= 0.5	R.R.= 0.3
Replace of roof tiles	14	20	30
Replace of external wall sidings	10	14	18
Replace of external wall mortar finish	7	9	11
Replace of external wall stucco finish	8	9	10
Wooden flush door	6	9	12
Wooden panel door	9	11	13
Aluminium door	15	19	23
Aluminium sliding door	15	20	24
Kitchen units	10	14	19
Gas instant boiler	7	8	10

R.R.: Remaining rate

4. ESTIMATION OF HOUSE REFURBISHMENT WORK COST

We interviewed specialists of house refurbishment, each of them belongs to 3 major housing production and/or sales companies in Japan. They provided us with 30 real cases of cost estimation documents presented to the clients. We analyzed these documents and consulted with published documents on building cost data to estimate unit cost of each item included in house refurbishment work. Looking into the real cases, we found that material cost and labor cost are sometime separately described and sometime not separated even in one company's similar cases. And in almost case temporary work cost is an independent item, but some had no such item in the estimation document. Each company has a constant profit rate irrelevant to the content or the scale of the work. To estimate "standard" unit cost of house refurbishment, we needed benchmark cases, so we selected some from the provided cases whose content seem to be average and clear. We must omit the detail of each cost value because of space limitation.

5. ESTIMATION OF THE LCC OF A DETACHED HOUSE

5-1. Model and refurbishment frequency

We selected one of the provided cases as the model of the LCC, shown in the table-6 which was an ordinary one in 1960s and may be rather small from today's standard.

Table-6. Model house for LCC estimation

Location	Kobe city, Japan
Age	30 year-old
Rooms	5 bed rooms and dining kitchen
Construction	Traditional wooden construction
Total floor area	99.8m^2
Area of exterior wall	94.1m^2

The lifetime of the model house is assumed to be 30 or 60 years; 30 years is so-called average lifetime of Japanese detached house, 60 years is assumed as elongated life. The estimated refurbishment interval of each parts of the model house is shown in the following table. These figures are decided based on the replace/repair intervals mentioned in 3-4 considering that in real case refurbishment may be carried out per room.

Table-7. Replace/repair intervals of model house parts

Part	Interval	Refurbishment in 60 years life
Exterior wall finish	15	3
Rain drainage piping	16	3
Veranda	16	3
Shutter	36	1
Living room	19	3
Private room	30	1
Entrance	21	2
Corridor	19	3
Kitchen	19	3
Unit bath room	17	3
Dressing room	18	3
Toilet	24	2
Boiler	11	5
Electric wiring	28	2
Water supply piping	26	2
Sewage piping	26	2
Gas piping	13	4
Antenna wiring sheath	13	4
Roof	15	3

5-2. Calculation of LCC

We followed ASTM to calculate LCC with following formula.

PVLCC=IC+PVM+PVR+PVF-PVS

[IC: Initial Cost, PVLCC: Present Value of Life Cycle Cost, PVM: Present Value of Maintenance(refurbishment) cost, PVR: Present Value of Replacement(refurbishment) cost, PVF: Present Value of Fuels(utilities), PVS: Present Value of Selling after use]

In Japan, re-sale of used housing parts is very difficult and demolishing fee is needed at the end of a house usage, and this is why PVS is prefixed minus.

Some conditions are assumed to calculate LCC; 1) the location of the model is suburban and the environment is not severe, 2) structures will not modified, and refurbishment will occur because of deterioration of materials or parts 3) the specification or grade of each part will remain same level in the refurbishment work, 4) extension of a house or change of room function will not occur during the lifetime.

With estimated unit cost and quantity of construction in the supposed refurbishment works at each year, you can calculate the direct construction cost of each repair work in the lifetime. Then adding temporary work cost (1.48% of direct construction cost) and the profit of the contractor(10.0% of the total cost of direct construction works), you will get refurbishment (or repair) cost at each year during the lifetime of the model.

In the calculation of present value, we supposed that the capital rate and the inflation rate is same. Then we assumed the new construction cost as 550,000yen per “tubo”(3.3m^2), demolishing cost as

12,000yen per m^2 and utilities cost as 250,000yen per year (this figure is based upon a statistical research of Japanese home economies).

5-3. Result of calculation

The LCC of 30 years life is 35.9 million yen which is 2.16 times of new construction cost, and that of 60 years life is 54.0 million yen, 3.25 times of new construction cost. Within the part of refurbishment (repair) cost in the LCC, the external part of a house, bathroom and kitchen take 70% of the total (see Fig.-5). We made the same studies on othe two model houses, and we obtained similar results.

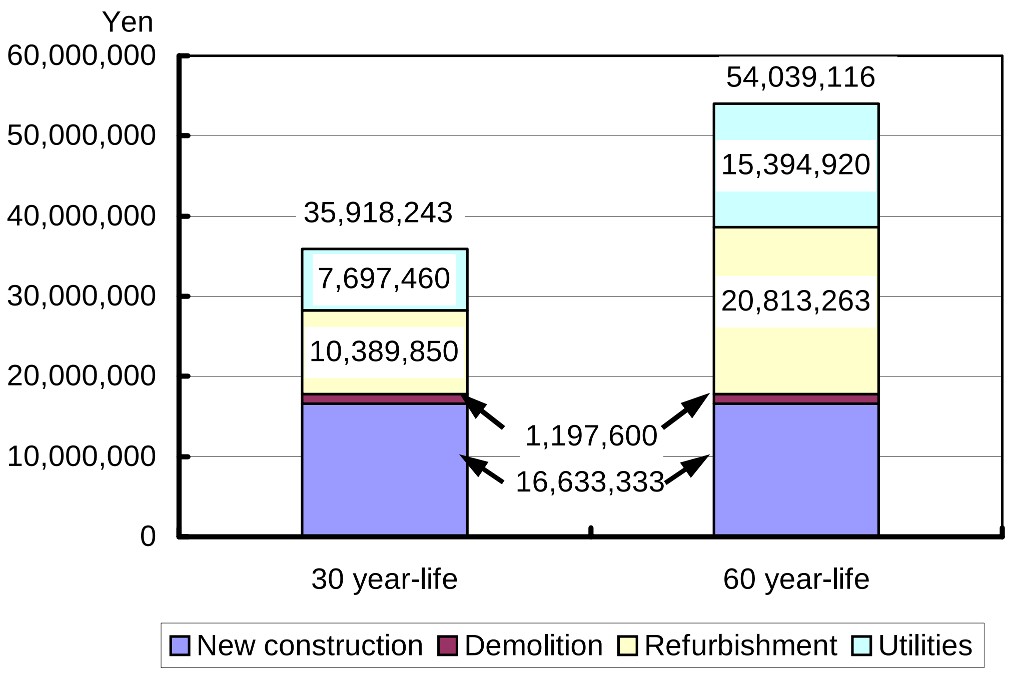

Fig-4. LCC of the model

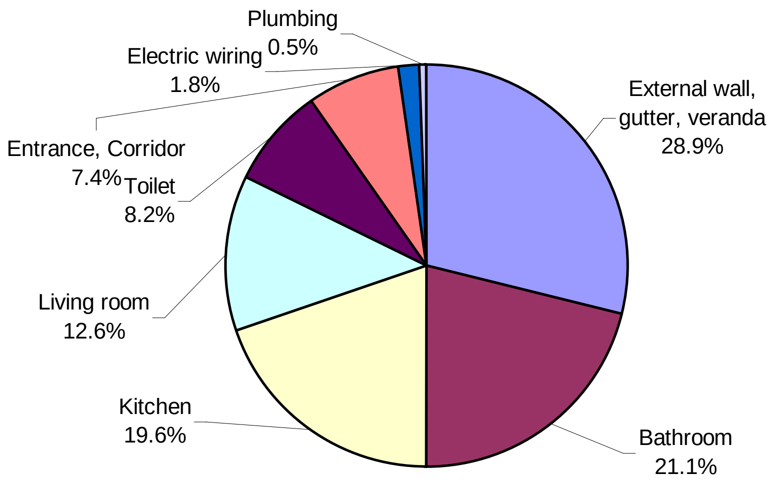

Fig-5. Breakdown of refurbishment (repair) cost

6. CONCLUSIONS

We calculated the life cycle cost of an average Japanese detached house in two cases. One, LCC of 30 year life is 2.16 times of new construction cost, and the other, that of 60 year life is 3.25 times. When you use a house for 60 years, you will save 17.8 million yen compared to rebuild the house in 30 years. This means you can save 107% of new construction cost during 60 year usage. In the near future, demolishing cost will rise because of the increasing need for environmental reservation, and technical development will help lowering the refurbishment costs. Then the longer usage of a house will be more profitable as for LCC.

ACKNOWLEDGEMENTS

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The main part of this study was also presented at the ILCDES2000 in Helsinki, May 2000.

REFERENCE

[Komatsu94] Some Theoretical Studies on Making a Life Table of Buildings (published in Japanese), Komatsu,Y, Journal of Architecture Planning and Environmental Engineering, No.439, Sep. 1992 pp.91-99, Architectural Institute of Japan.