Methods for Surveying And Describing the Building Stock CIB/W70 Seminar

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March 16-20, 1981, Tällberg, Sweden

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A NEW METHODOLOGY FOR THE MAINTENANCE OF A PERMANENT HOUSING STOCK INVENTORY THE CASE OF FRANCE

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ABSTRACT

The building stock comprises the set of structures located within a specific area. One of the main building stock fields is the housing stock which is accounted for through the method of permanent inventory. Such a method considers that stock as a resultant of a flow of units put into service and of others that are withdrawn. Traditional techniques for measuring the withdrawal flow had, however, limitations that reduced very much their use. The author has developed a series of functions ("V" functions) that make possible the rigorous statistical analysis of that withdrawal flow. This, in turn, allows for a better understanding of the evolution of the stock. Those results have been obtained by the author in the context of a research for the French "Ministère de l'Environnement et du Cadre de Vie".

I. INTRODUCTION

The building stock comprises the set of structures located within a specific area. Accounting for these structures has always interested statisticians. It has in fact, been more than a century that several countries have collected information in the number of houses, factories and sometimes health and education institutions. However, since such information is essentially drawn out of censuses or fiscal surveys, it is perceived as a bi-product of population accounts or of fiscal sharing propositions. It is only since the last war that a systematic accounting of the building, and in particular that of the housing stock, has been developed. This paper deals precisely with the numerical representation of housing through the permanent inventory method.

After out lining the traditional approach and underlining its limitation, this paper develops a new methodology that has since been applied to the maintenance of permanent housing inventory in France and, soon, to be applied in Canada.

II. HOUSING FLOWS AND STOCKS: THE CLASSIC APPROACH

1. New Units Flow

The new units flow comprises housing units completed in a given year, whether those resulting from the transformation of structures originally intended for other uses, or those accrued from the subdivision of larger housing units.

2. Housing Stock

The housing stock is accounted for, or listed, in housing surveys. Such information describes the final allocation of main and second residences and vacant units. It is, however, difficult to statistically follow up the dwellings in each of these categories due to the constant transfer from one category to the other.

Moreover, since censuses and surveys register the construction period of these buildings, it becomes possible to reconstruct the development of the building stock by "cohorts". Such an approach was used in a study undertaken for the Ministère de l'Environnement et du Cadre de Vie in France (1).

3. Retirement Flow: The Traditional Approach

With regard to the retirement of dwellings, the most interesting but also complex problems are those related to the measurement of social behaviour. In fact, what is the average useful life of dwellings? What are the prospects of their survival? Do old dwellings fare equally relative to more recent ones? Under what circumstances can changes in social behaviour with regard to retirement be observed?

The relevance of all these questions can be appreciated by taking into account the fact that the replacement of deserted buildings takes up a considerable amount of newly-constructed buildings. Moreover, retirement gives society the opportunity to express its preferences with regard to dwellings, old or otherwise. And so on yet, it was not until the 70's that objective solutions to these problems became possible. Today, analysis of building stock can be based upon two distinctive yet complementary methodologies known as the perpetual inventory (2), and the benchmark methods (3).

The first of these methods permits the recursive calculation of the stock in time t by adding the allocation flow between t-1 and t to the t-1 stock, and subtracting from it the retirement flow which has occured in the meantime.

The second method results from the intermittent but direct measure of a specific stock. With regard to housing, the "benchmarks" are made up of information drawn out of censuses and surveys.

Both methods contain certain elements of knowledge but also present some insufficiencies. Their combination appears to be the only way of drawing up detailed information on the building stock.

In the balance of this paper, we shall try to validate the combination of these two methods.

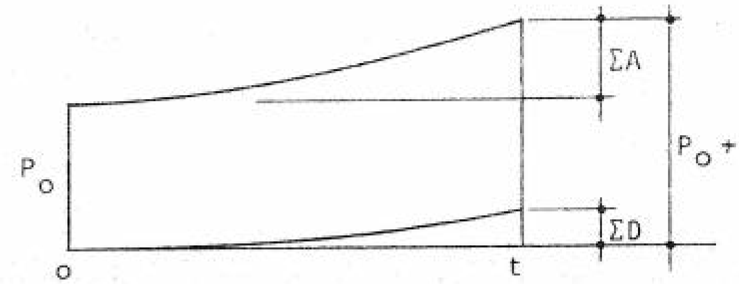
A. PERPETUAL INVENTORY

As with all perpetual inventories, those of the building stock are dependent, in theory, on three types of information. First, the volume of the stock in the year of origin must be known. Then, a chronological list of their allocation and occupation must be available. Finally, information on their retirement flow should also be at one's disposal.

Given that we are already in possession of complete information on the original stock P_o, on the new units flow (A) and the retirement flow (D), the stock in any t year can be determined.

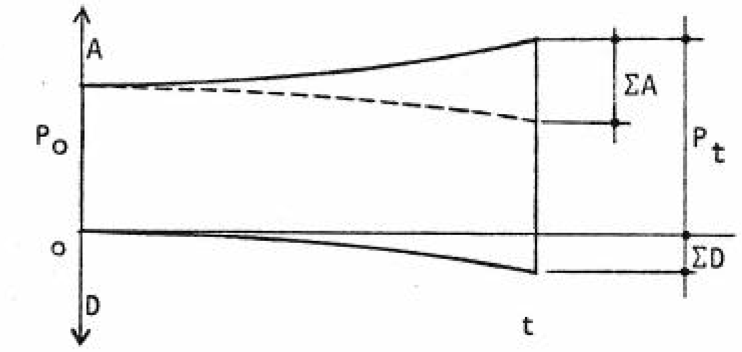
$$P_t = P_o + \sum_{t=o}^{t} (A - D)$$

The following diagram graphically expresses this equation:

1) 

If D is expressed along the negative Y axis, the graph would be the following:

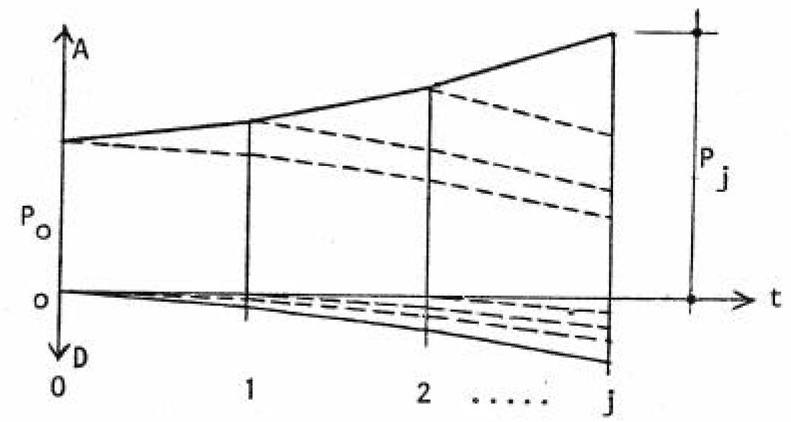
2)



If, however, one wishes to know the stock P_j broken up according to the construction period, the latter would be considered as the amount of stock constructed during these periods.

Graphically, such a disaggregation can be represented as a generalisation of the preceding graph.

3)



Although appealing, the method of the perpetual inventory cannot be applied by itself. Firstly, available statistics concerning the retirement flow are incomplete. In most countries, statistics concerning the number of dwellings units constructed each year are reluctantly supplied by the administration responsible for their compilation. Moreover, it is known that building permits, which are the principal source of statistical information, are not required for certain marginal types of dwellings. Finally, there is practically no information available on the allocation of buildings formerly intended for other uses; these are, of course, not very numerous.

Secondly, if the unit flow lists suffer somewhat from their uncertainty, those of the retirement flows are practically inexistent. In fact, in most countries only very fragmented facts on demolition and destruction by disaster can be found. By the same token, there is nothing available neither on progressive abandonment, nor on allocation for purposes other than habitation, which at certain times can reach a considerably high level.

Eventually, by admitting that P_o is known, a series $P_o - \Sigma A$ can be constructed, the precision of which depends on that of the series of retirements (diagram 1 above). It would be impossible, however, to subtract the retirements and subsequently deduct the value of the stock P_j (diagram 2 and 3 above).

In an attempt to fill this gap, statisticians have tried to construct hypothetical functions of retirement. Drawing upon procedures used in the evaluation of capital stocks, these functions were applied to retirement in the building stock, which naturally implies their applicability to retirement in dwelling units. However, it is not very likely that any of these hypotheses correspont to reality, as we will se later.

It is therefore, evident that it is "a priori" difficult to strictly apply the perpetual method inventory. On the other hand, it would "a posteriori" become a possibility after having recourse to statistics which are the benchmarks of censuses and surveys on housing.

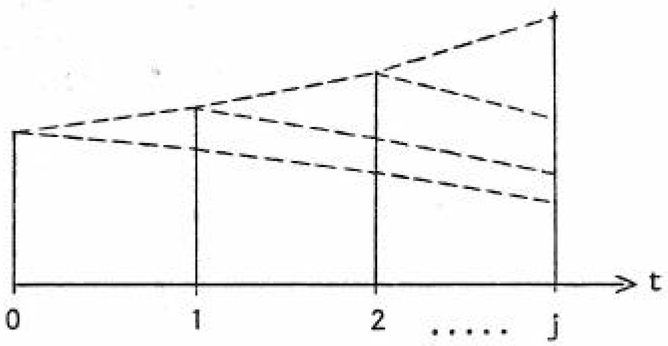
B. BENCHMARK METHOD

For over a century, censuses have supplied information on the volume of the building stock. In fact, since their origin and in whatever country, the concept of identy between the number of households and the number of housing units has permitted the drawing up of very reliable statistics on the residential stock.

Since the beginning of the 60's these same censuses give information on the periods during which construction took place. Such information is explicitly supplied in the case of France. They permit most particularly, the construction of intercensus demographic "cohorts" especially since 1962.

The benchmarks constituted by the censuses are completed by those of the housing surveys which are presented in a similar form. In fact, all basic information on the total dwelling stock is supplied by censuses and surveys (1). The following diagram outlines the information made available through the benchmarks method:

4)



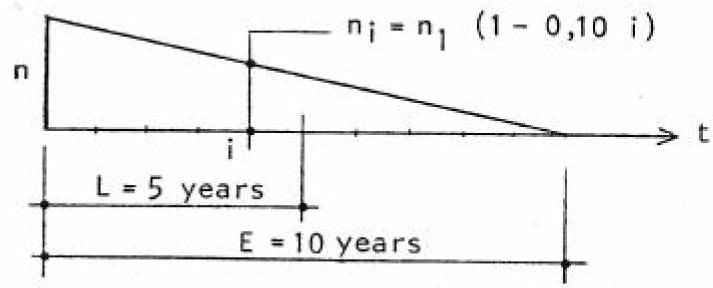
If this diagram is compared with diagram 3) above, it must be noted that the benchmarks supply all the missing facts necessary to draw up a perpetual inventory. However, is it possible to take a step backwards so as to reconstitute the aforementioned list from facts compiled from benchmarks which are duly completed by a profile of allocations, more or less known?

In order to answer this question, three points should be elaborated: the first concerns the chronological stratification of the perpetual inventory, the second, the formalisation of the statistical rules of retirement, and the third involves the establishment of those laws according to the observations supplied by the benchmarks.

C. COMBINATION OF THE TWO METHODS

Let us take a stock constituted between years 1 and 5. We admit that the units constructed during each of those five years disappear in a linear manner at the annual rate of 10% relative to their initial number. In this case, the average lifespan L of these units is 5 years and their maximum lifespan 10 years. The diagrams of the survival of the units constructed in one year n would thus be the following, where i represents the index of the year of survival relative to the year t where the stock n has been constituted.

5)

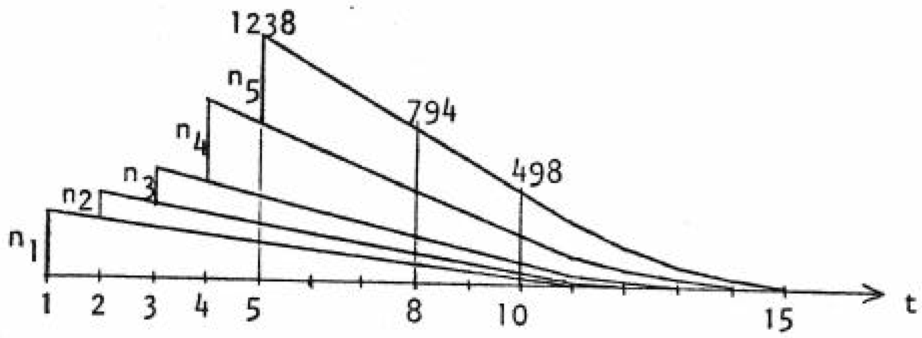


The perpetual inventory consists of adding the surviving units of stocks n implemented each t year of t = 1 to t = 5.

$$P_j = \sum_{t=1}^{t=5} n_t \; (1 - 0.10(j - t))$$

Having given the values of the initial stocks n, for example 300, 140, 200, 400 and 440, one can easily calculate the total volume of the stock in any given year. Thus, at the end of years 5, 8 and 10, the volumes would be 1238. 794 and 498 units respectively. Moreover, the stock would disappear definitely at the end of year 15. Diagram 6) below shows these results.

6)



Supposing that we are currently in possession of the aforementioned stock, showing that at years 5, 8 and 10 exactly, the stock measured 1360, 1035 and 600 units instead of those previously calculated. It is obvious that the hypotheses which had been used to make these calculations are rendered at once invalid.

In effect, we could first correct the series of stocks by modifying them by a coefficient k_1 so that the total stock in year 5 would be 1360 units instead of 1238. We could also prolong the lifespan L so that the stock level in year 8 would be at 1035 units instead of 794, while continuing to measure 1360 in year 5 (which implies a iteration producing a new coefficient K_2 to correct series n).

But it would be impossible to "model" the stock with the linear disappearance and whatever values are adopted for K and L, so that it "passes" through the three points observed. In other words, non-linear disappearance hypotheses must be adopted. But what are the disappearance or retirement rules likely to be considered?

D. THE TRADITIONAL RETIREMENT FUNCTIONS

The first works on the laws of capital stock retirement (or depletion and depreciation) date back to the '30. They nonetheless remain relevant to today's reality (5). Koumanakos describes four types of laws characterized by the retirement rate distribution functions measured in relation to the initial stock up to the very end of service life. The functions are as follows:

1 - straight line

2 - geometric decay

3 - bell-shaped

4 - sudden exit

By integrating these functions we obtain the functions of the corresponding μ survival rate measured in comparison to the initial stock:

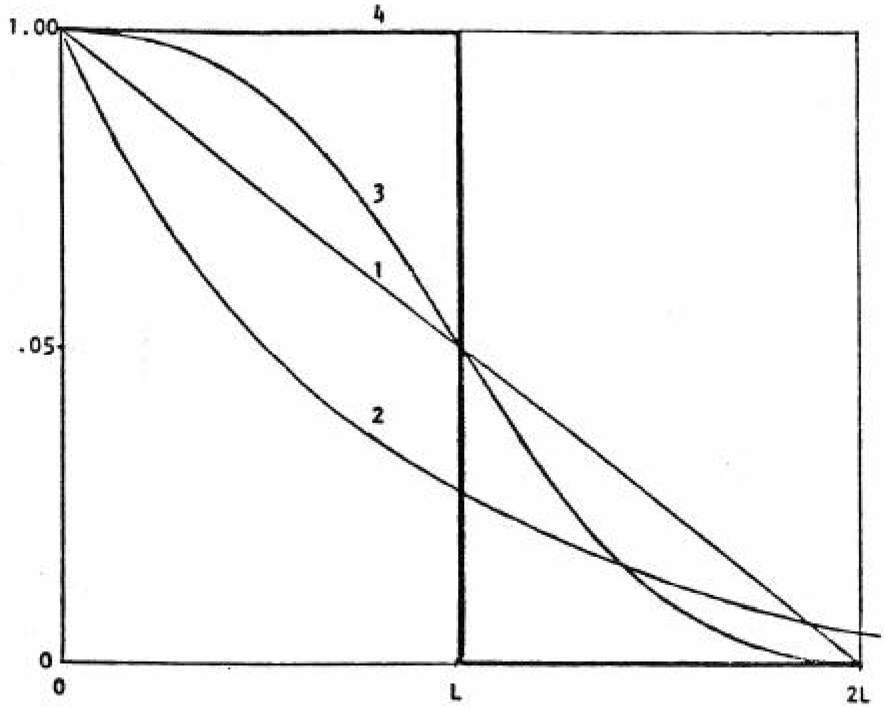


Figure 1. The depletion and depreciation functions of capital stocks.

Faced with the difficulty of choosing among these functions, alternative studies have been formulated (6). However, it is clear that only functions 1 and 3 can be used to represent the survival rate of the housing supply. Indeed, the geometric decay function corresponds more to depreciation than to withdrawal. Similarly, the sudden exit function applies only to "individuals" and not to stocks.

In the short run, the straight line profile can be used to analyze retirement, for example, between two "cross-sections" such as censuses or studies. However, in the long run, only the normal function corresponds in any way to reality. At the start of the period, there is very little withdrawal, and for good reasons: the dwellings are new and the rate of withdrawal due to disaster, demolition, or irreversible abandonment, is slight. This rate increases, therefore, as time goes by. The surviving stock thus tends to decrease, which gradually compensates for the increased rate itself. Hence the typical WS3 curve, generally used, we should recall, by North American institutions in keeping a perpetual inventory of residential real estate.

It should be noted that the WS3 function cancels out into 2L. This is a "book-keeping" device, solely applicable to the development of the current stock. It is clear that certain buildings survive beyond all life expectancy. This is the case with "classified" buildings whose use and preservation follow, by their very nature, special laws.

E. THE LIMITATIONS OF THE WS3 FUNCTION

The latest censuses have provided very important information on the development of the housing stock. Whether it be in the United States, Canada or France, two co-existing phenomena can be noted. On the one hand, a very large part of this stock is still composed of very old dwellings. The inevitable conclusion is that the average life span of housing - at least of the oldest housing - is much longer than one would otherwise think. On the other hand, the housing supply built during the last century, or even before the last war, is now rapidly declining. Therefore, the average service life of this housing is rather close to the limit or end of service life, that we will call E.

In other words, the L/E relationship is more than 0.5, which means that the WS3 function does not reflect reality. Is it possible, then, to develop functions capable of more adequately reproducing the survival rate of the different housing supplies? It is these functions, herein called V functions, that we shall develop in part III.

III. THE "V" SURVIVAL FUNCTIONS

1. An uni-modal distribution of the absolute retirement rate

We will first of all adopt the polynomial approach, for the reason that modal patterns are awkward to deal with and also more difficult to integrate. Moreover, polynomial simulations such as those developed by Schiff (7), offer a degree of accuracy that is sufficient for present needs.

The f(x) function representing the no. 3 bell-shaped pattern above, can be considered a special case in the family of functions that have the following general make-up:

$$\mu = f(x) = ax^m \ (0{,}5\ E)^{-(m+3)} (x-E)^2$$

These μ functions represent uni-modal patterns of the absolute rate of retirement, (in relation to the initial stock) (8).

The values of a are determined by postulating:

$$\int_0^E f(x)\ dx = 1$$

which, after integration, becomes as follows:

$$a = 0{,}5^{m-4}\ (m+1)\ (m+2)\ (m+3)$$

It can be observed that a, and consequently μ,, cancel each other when m = 1. In other works, the function μ offers a double possibility of simulation. For a value of M lying between -1 and 0, it simulates the negative exponential function (see distribution unit 2 above). For values of m higher than 0, the function μ simulates the uni-modal distribution.

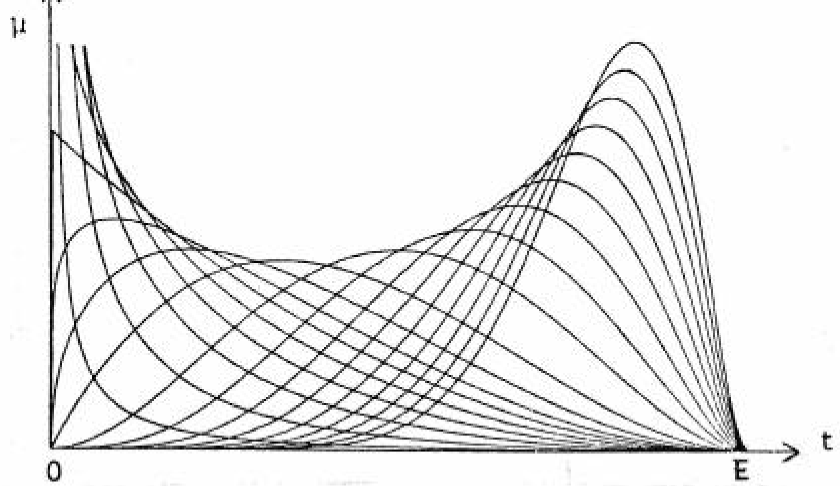


Figure 2. Retirement rate μ for several values of m.

2. The V functions

The f(x) functions of the absolute withdrawal rates make it possible to easily determine survival rates or V functions. Thus,

$$V_i = 1 - \int_o^i f(x)\, dx$$

Figure 3 provides the value of the V functions of survival rates.

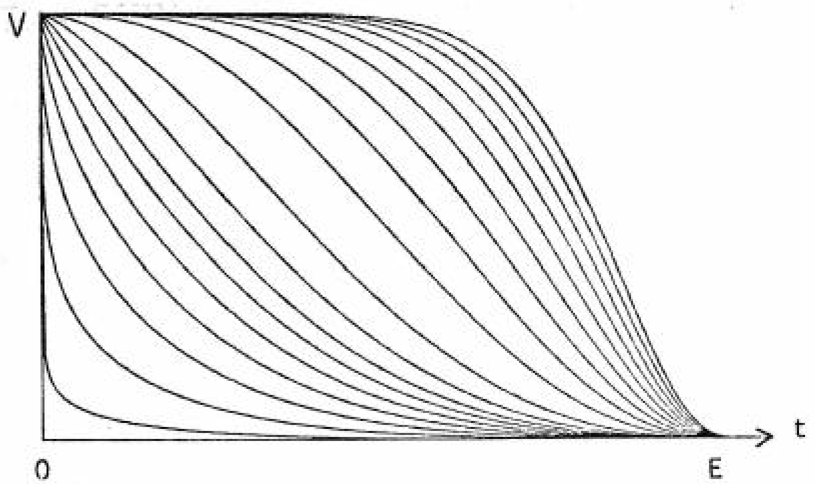


Figure 3. Survival functions V for several values of m.

The average service life L is a function of m and of E. It results from the integration of the complementary function of $F(x) = \int f(x)\, dx$.

$$L = E - \int_o^E F(x)\, dx$$

and $$L = E \frac{m + 1}{m + 4}$$

3. Determination of parameters

The parametric determination of the functions V permits the modelling of a stock of which we know, approximately, the allocation and at least three benchmarks. The latter are constituted from the observation of the volume of the stock at the top of the last allocation, together with two subsequent observations sufficiently distinct and apart for their differences to be significant.

Supposing that we wanted to establish the E and m parameters in a survival function like that applied to component allocations of a stock between time TMIN and time TA, and that this produces a surviving stock of volume A, B and C at times TA, TB and TC. This implies that we would have a chronological series of allocations, and the volumes A, B and C in question.

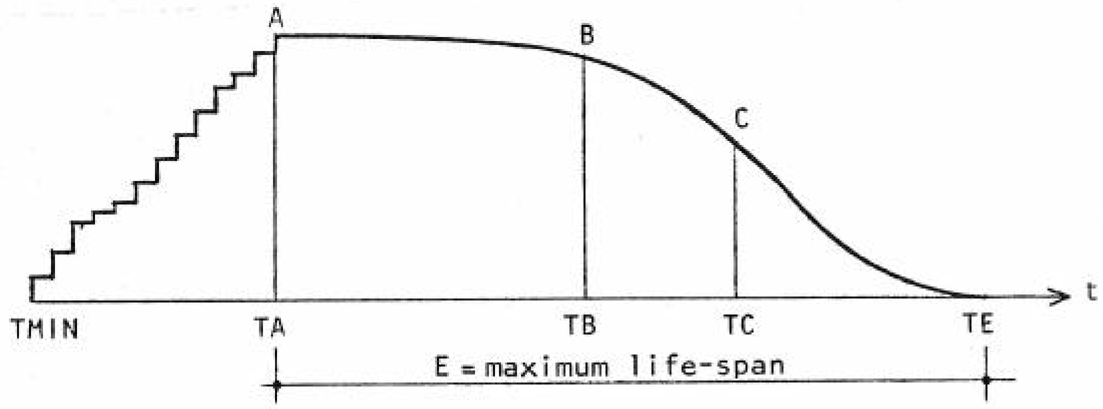


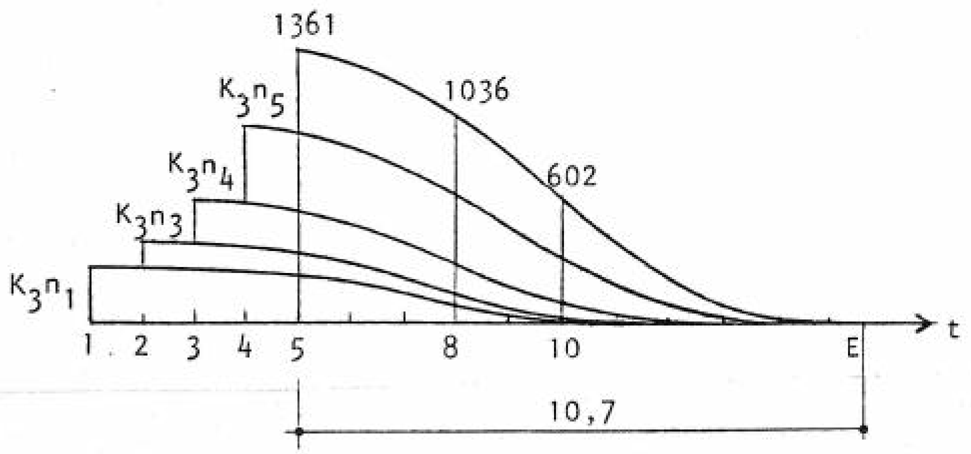
Diagram 4. Typical profile of a "cohort" of dwellings.

The sought out function can be established with the aid of an iteration. The iterative procedure must determine the value of the following parameters:

- K, or corrective coefficient of the chronological series of allocations
- m, characteristic of the type of stratum profile
- E, maximum life-span.

We have constructed an algorithm which enables us to establish the relevant parameters. The corresponding calculation programme was applied to the example previously left in abeyance with respectively, the volume in TA, TB, and TC of 1262, 1036 and 600 units as facts. The results give $K_3 = 0.95$, $m = 3.9$, $E = 10.7$ years and $L = 6.95$ years. They are shown in the following diagram.

7)



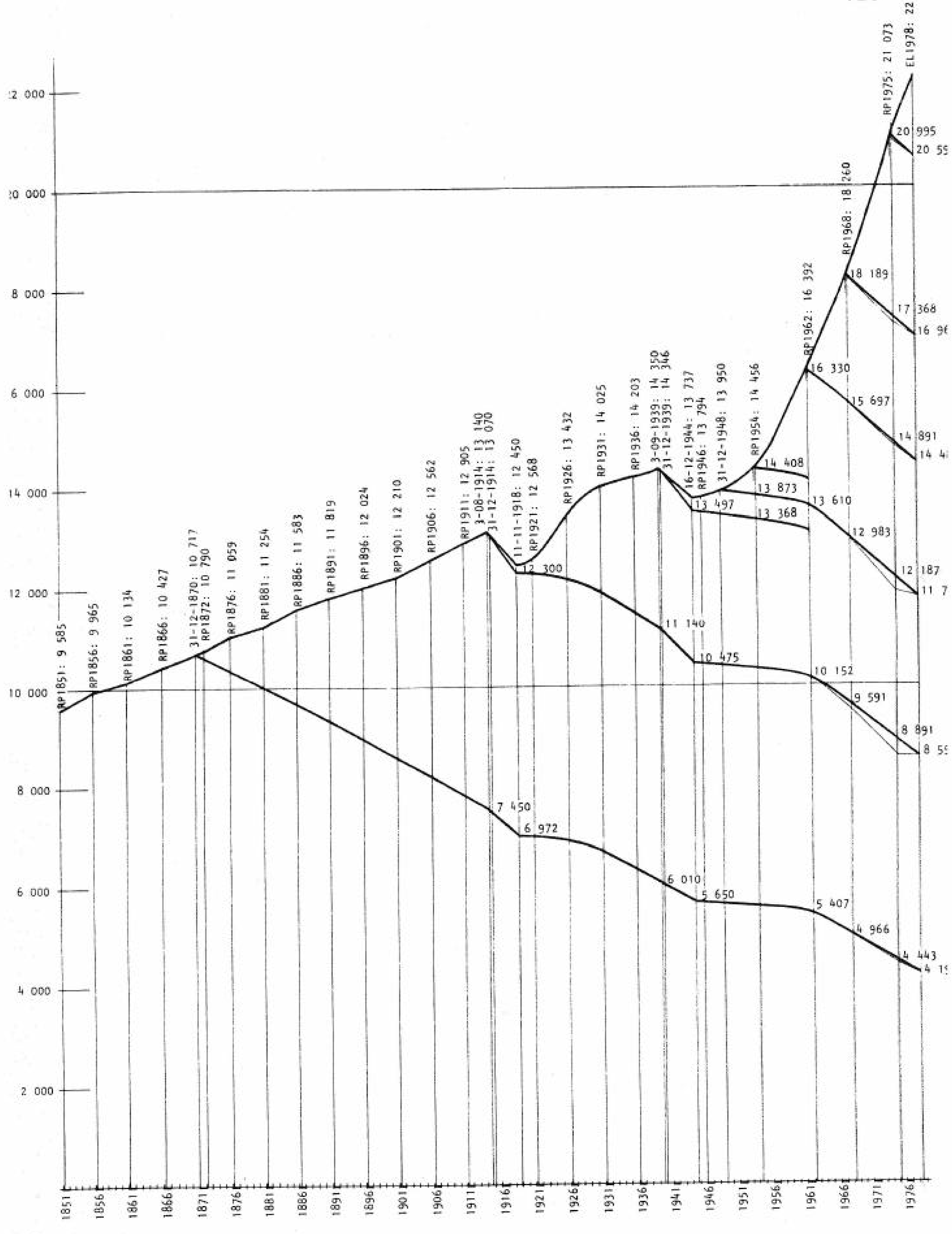


Diagram 5. The French Building Stock since 1951 by construction periods. (In thousands of units)

IV. AN EXAMPLE: THE FRENCH BUILDING STOCK

The French stock was the first to be analysed by means of V functions. Beforehand, we reconstructed the entire volume of the stock from 1851 to 1978. Diagram 5 illustrates this reconstruction (4). The breaking up into "cohorts" according to the construction period will be noticed, traumatism brought about by two World Wars, long periods before recovery, the "boom" from 1958 onwards, acceleration of the retirement rhythm after 1962 and also other characteristics of its development.

The modelling of the stock is done with the aid of the methodology shown below. The precision of the results fully ratify the approach. These results are shown in a table which features the characteristic parameters of V functions as well as the measure of flows, stocks, and average life-span of each "cohort" of dwellings. For example, for the 1949-1961 "cohort" of the French Building Stock, one will have the following results.

COHORTE 1949-1961

VALEUR FINALE DE M = 2.32473
VALEUR FINALE DE E = 159.46394

VIE MOYENNE = 83.82567

ANNEE	FLUX ENTREE	FLUX SORTIE	STOCK	AGE MOYEN
1948	74219		74219	.50
1949	91888	0	166108	.95
1950	101982	0	268090	1.40
1951	114598	2	382685	1.83
1952	152461	6	535140	2.17
1953	167036	12	702164	2.53
1954	221742	23	923883	2.80
1955	238533	38	1162378	3.13
1956	282268	61	1444585	3.42
1957	300767	92	1745259	3.74
1958	330411	134	2075537	4.07
1959	325385	190	2400732	4.45
1960	325880	261	2726350	4.86
1961	0	350	2725999	5.86
1962	0	460	2725539	6.85
1963	0	591	2724947	7.85
1964	0	745	2724202	8.85
1965	0	920	2723281	9.85
1966	0	1117	2722164	10.85
1967	0	1337	2720827	11.85
1968	0	1578	2719248	12.85
1969	0	1841	2717406	13.85
1970	0	2126	2715280	14.85
1971	0	2432	2712848	15.85
1972	0	2758	2710089	16.84
1973	0	3104	2706985	17.84
1974	0	3469	2703516	18.84
1975	0	3854	2699661	19.84
1976	0	4256	2695405	20.84
1977	0	4676	2690728	21.84
1978	0	5113	2685614	22.83

V. CONCLUSION

To conclude, it is essential to question the significance of V functions. These represent theoretical survival profiles which are ajustable and as a result, describe development of a stock within these recognised benchmarks. It is clear that outside the period limited by benchmarks, the stock may have undergone a development, at times, quite far-removed from that described by the adjusted function V.

For example, from the beginning, a given society can adopt a certain position with regard to its stock. This position can be characterised by a function V of m_1, and its maximum life-span established by benchmarks A and B. Then, should there be a sudden demographic expansion, the rythm of the stock in question can rapidly decrease as is shown between benchmarks C-D, by a function having $m_2 > m_1$ as parameters, and/or $E_2 > E_1$ as its maximum life-span.

These changes can occur many times during the life-span of a given stock. Thus, function V exclusively represents the social behaviour with regard to retirement of the building stock during a specific period. It can not give a complete picture of the development of the stock in question. On the other hand, by observing these changes we can see that considerable changes exist in behaviour with regard to retirement of building stock.

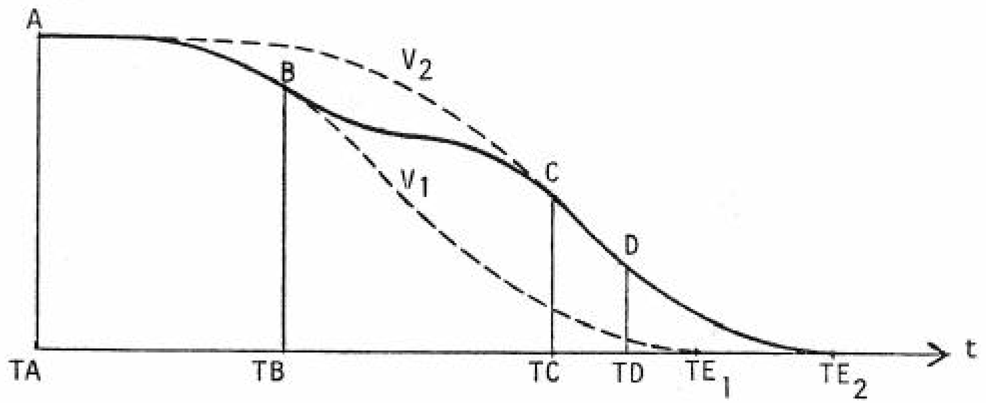


Diagram 6. Typical profile of a "cohort" of dwellings with changes in the retirement flow.

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(3) This method is in no way different from the weighted data obtained from cross-sectional observations such as those provided by exhaustive listings or samples with low levels of uncertainty.

(4) See for example the studies of B.E.A., Fixed Non Residential Business and Residential Capital in the United States, 1925-1975, N.T.I.S., PB-253-725, June 1976; P. KOUMANAKOS, Alternative Estimates of Non Residential Capital in Canada, 1926-1975, Construction Division, Statistics Canada, Ottawa, Dec. 1975.

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