Micro-Economic Analysis of the Process of Design, Construction and Operation of Houses

Analyse micro-économique du processus de projet, construction et exploitation des bâtiments

Micro-ökonomische Analyse des Prozesses Entwurf — Bau — Betrieb im Hochbau

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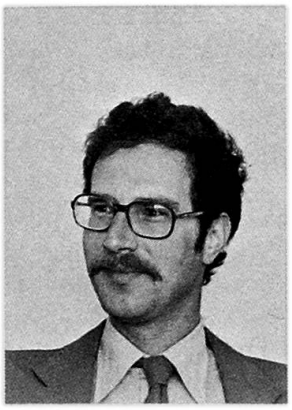

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SUMMARY

Although it is well known that housing is expensive, the real prices are unknown. The indirect costs, however, are the result of a process of rough estimation and even negotiations. This means that the resulting construction price is, at best, a weak basis for calculating the period costs of housing services. Moreover, this calculation should also be a function of the different lifetime experiences of the various building components. Construction and operation costs are related to one another to facilitate decision making by government, project developers, construction companies and consumers of housing services.

RÉSUMÉ

L'habitat est cher, mais personne n'en sait le prix réel. D'une part les coûts directs de construction sont faciles à chiffrer. D'autre part, les coûts indirects, résultant d'un processus d'estimation et même de négociations sont difficiles à fixer. Il s'ensuit que le prix de construction est une mauvaise base pour déterminer les coûts périodiques des services de bâtiment. Ce calcul se base en outre sur des composantes du bâtiment ayant une durée de vie différente. Les processus de construction et d'exploitation sont mis en étroite relation pour faciliter la prise de décision des administrations, des sociétés immobilières, des entreprises de construction et des utilisateurs.

ZUSAMMENFASSUNG

Für den Konsumenten ist Wohnen bekanntlich teuer; die wirklichen Preise sind jedoch unbekannt. Im Bauprozess sind die direkten Kosten verhältnismässig leicht festzustellen. Die indirekten Kosten jedoch ergeben sich aus grossen Schätzungen und Unterhandlungen. Das Ergebnis, der Baupreis, ist deswegen eine unzuverlässige Basis für die Berechnung der Kosten des Wohnprozesses. Die Kalkulation soll von der unterschiedlichen Lebensdauer der Komponenten des Gebäudes abhängen. Bau- und Betriebskosten werden gesamthaft berücksichtigt, um den Entscheidungsprozess der Behörden, Immobilien- und Baugesellschaften sowie der Benützer zu vereinfachen.

1. INTRODUCTION

In The Netherlands, and probably in many other countries, one can plainly state that 'we build too expensively and pay too low rents'. Cause and consequence are to a large extent due to government. As soon as we decide housing to be a merit good, we build for and rent from the state. This causes two interrelated phenomena:

- separation of supply and demand of housing services,
- dependence of the housing issue on other political issues.

These two problems did us no harm in the period of fast economic growth: government had enough money to invest, and shortages in exploitation could easily be covered. Today, the lack of growth, and the government deficits together with increasing unemployment, forces us to pay more attention to the building and exploitation process, and than we will become aware of the fact that, for a long period, houses were built and exploited without the exact costs being known.

Approaching the house as a durable production good - it produces living services - we see it to be complex to other durable goods. As in other production processes, the house can be split up into parts which can be produced and consumed rather independently. But in contrast to most other processes, we find a series - in time - of production processes and a changing building. A series of rehabilitations can be foreseen, and they result in an adaptation of the building to the actual desires and possibilities.

Estimations should not start with the building process, but with the consumption process. Given the amount of money available for housing, a choice has to be made of the possibilities of living accomodations. The possibilities are combinations of building parts with different costs and different levels of services. To calculate period costs information is needed about investment costs, lifetime, complementary expenses and interest rates. The costs after future rehabilitation depend on whether there be replacements, and, if so, whether these replacements be indentical or with an increased level of service.

The model can - and probably will - be computerised to facilitate computations dealing with different assumptions about the variables. For serveral scenarios - with interest rates, energy and internal variables playing various rôles - the costs can be calculated.

2. THE DESIGN AND CONSTRUCTION PROCESS

2.1 Introduction

The ultimate goal of the building process is to deliver a building that will be used by the customers in the living services market. However the reason for a firm to operate on the building market is to earn an income. The individual demands for living services - most of the time interpreted by government - are the signal that the production of houses can be successful. This process will be successful for the firm if out of the sales all the expenses can be paid and the owners of equity-capital get their reasonable interest. Besides that some profit should be made to maintain the share of the market and to survive less profitable periods.

Cost calculation is the basis for the selection of projects and production methods that give the best chance of survival. For each product, it should be clear which costs have to be made during the production: not only the costs directly connected to the actual project, but also the indirect costs depending on the construction firm and its size. The choice of construction methods and the calculation of profits depend on direct costs as well as on indirect costs. The main problem in the design-and-construction process will be the allocation of these indirect costs.

Attention will be paid to the methods available and useful for cost calculation. The choising of the methods is of great importance for the visualisation of the relation between the process of design-and-construction and of exploitation of houses.

2.2 Direct and indirect costs

The main difference between the way the construction process and most other processes are organized lies in the prediction of the flow of products: their kind and their quantity. In a process of mass-production the actions which give rise to costs are repeated continuously. The relation between the costs and the ultimate product can be found in a relatively easy way. In the construction industry most of the time only the direct costs and a small part of the indirect costs are calculated rather exactly. The majority of the indirect costs however are predicted as some percentage of the direct costs.

Direct costs are the costs of an action that can be reckoned immediately to a part of the product. Labour and material costs of laying bricks or of pouring concrete are easy to calculate as part of the product. The costs of a crane, supervising or shuttering are not direct costs. These kinds of services are counted as indirect costs, because they do not give in themselves rise to a special part of the product. In theory it is necessary and even possible to find the causal relation between these indirect costs and the product. However in practice it is very expensive to find out which part of the building is responsible for every dollar of these costs. Besides that, it is questionable if for every decision it is necessary to know 100% of the indirect costs. To solve this problem, we define three levels of indirect costs. Before these levels can be defined, it is necessary to discuss the relevant methods of costing, the way a building is split up into components, and the levels of aggregation.

2.3 Costing with production centres

The construction process is a case of made-to-order production, or something serial-piece production. The simple method of deviding costs by the number of products can't be used. Because every process is 'new', it has to be analyzed anew technically and economically. The only way to solve the problem of getting a good calculation and of having the possibility of later controlling the results, is to try to find the causal relations between actions and products.

The method which requires the screening of the whole process and the determining of what happens in every corner of the site is the production-centre method. The costs of every activity on or outside the site are brought in direct relation to that activity. Every activity takes place because the services are needed for other activities of for the final product. All costs can - directly or indirectly -

be transposed to the ultimate product by a limited number of steps. The activities are concentrated in production-centres, the costs are finally borne by the product.

A glance on the building site shows us a number of apparently unorganised people who are amazingly able to construct a building which can be used over a long period. But, in fact, we can see a large amount of processes with their own products. These products - foundation, structure, outside walls, inside walls, heating system, kitchen, etc. - together give the final product: the house. The products which together form the house are interesting for the cost estimating and dechecking procedure. These products are defined as elements for which activities concentrated in production centres are needed. In diagram 1 the production centres and elements are represented.

The defining of elements which bear the costs instead of the building as a whole does not totally solve the problem of finding the relations between the costs of production centres and the element/product. It is not sufficiently to find the causal relation, we also need the quantitive relation between these elements and the production centres. This is necessary to spread the indirect costs over the elements in a correct way. When the process of finding all these relations would be a waste, this does not mean that the remaining indirect costs have to be allocated to the building as a whole and as a lump-sum. The elements can be aggregated on two levels, with less of a loss of information.

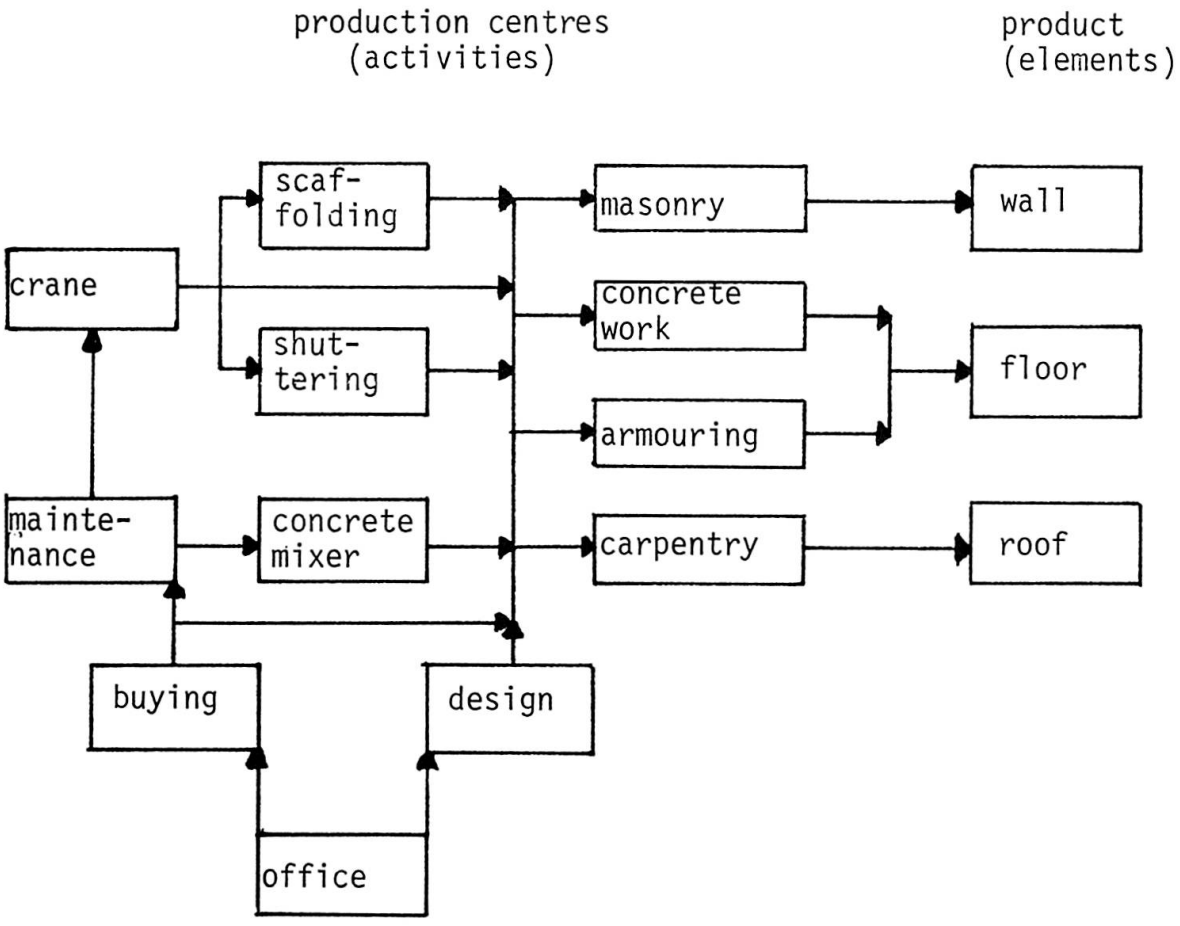

Diagram 1: Some relations between production centres (causing costs) and products (elements bearing the costs).

2.4 Aggregation of elements, and indirect costs on corresponding levels

As soon as we become aware of the fact that not all indirect costs can be allocated to the elements into which the building can be divided, we should define other allocation levels. These allocation levels are combinations of elements. On the other hand, the indirect costs have to be divided into groups corresponding with the groups of aggregated elements.

Viewing the indirect costs we see that like the direct costs an important part can be allocated to the elements. For a part of the remaining indirect costs it is possible to see the tie between the activities causing the indirect costs and a group of elements technically tied together. E.G. overground structure, underground structure, outside separation, inside separation, outside finishing, inside finishing, installations are defined as components-in-construction. For costs dealing with the site organisation even the ties with the building components are difficult to find. In this case, it will be possible to spread these costs over the phases in the construction process such as: structure building, rough finishing, detailed finishing and furnishing.

The indirect costs allocatable to the elements are defined as 'directly allocatable' and the other costs as 'indirectly allocatable'. In diagram 2 all costs and their relations to elements and combinations of elements are presented.

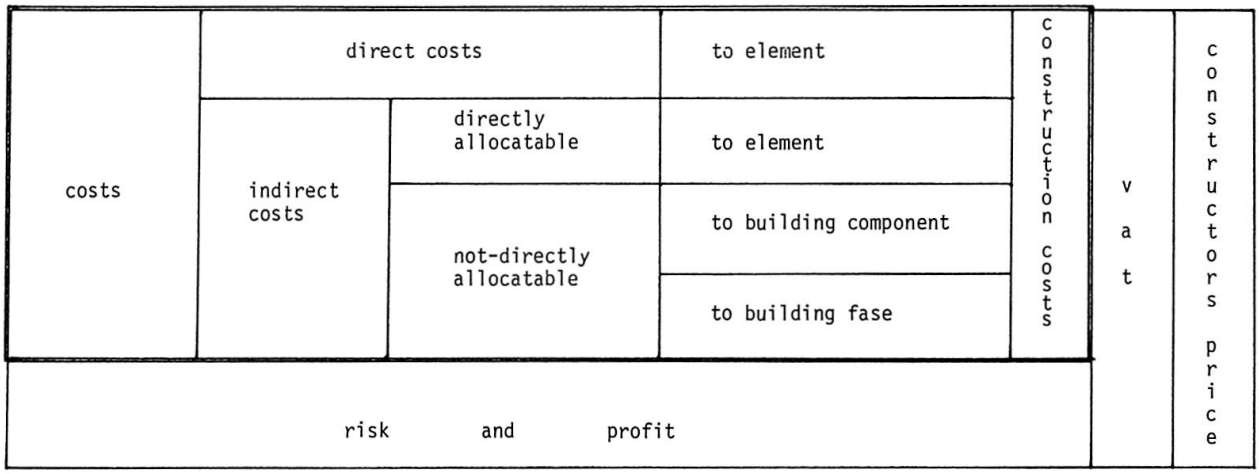

Diagram 2: Relations between costs and elements.

2.5 Costs Allocation Diagram

Since we now have defined different costs (different in the way in which they are allocated) and different groups of elements (different in their way of being tied together and the moment they appear in the building process) it is necessary to show how they are interrelated. In trying to use for the construction process the costs allocation method based on production-centres, we were not successful in allocating all indirect costs. After grouping the elements in components in construction and in construction phases, an economic allocation will be possible. Finally, we will find the costs of the building. In diagram 3, the relations between examples of direct and indirect costs and on the other hand elements and groups of elements are shown.

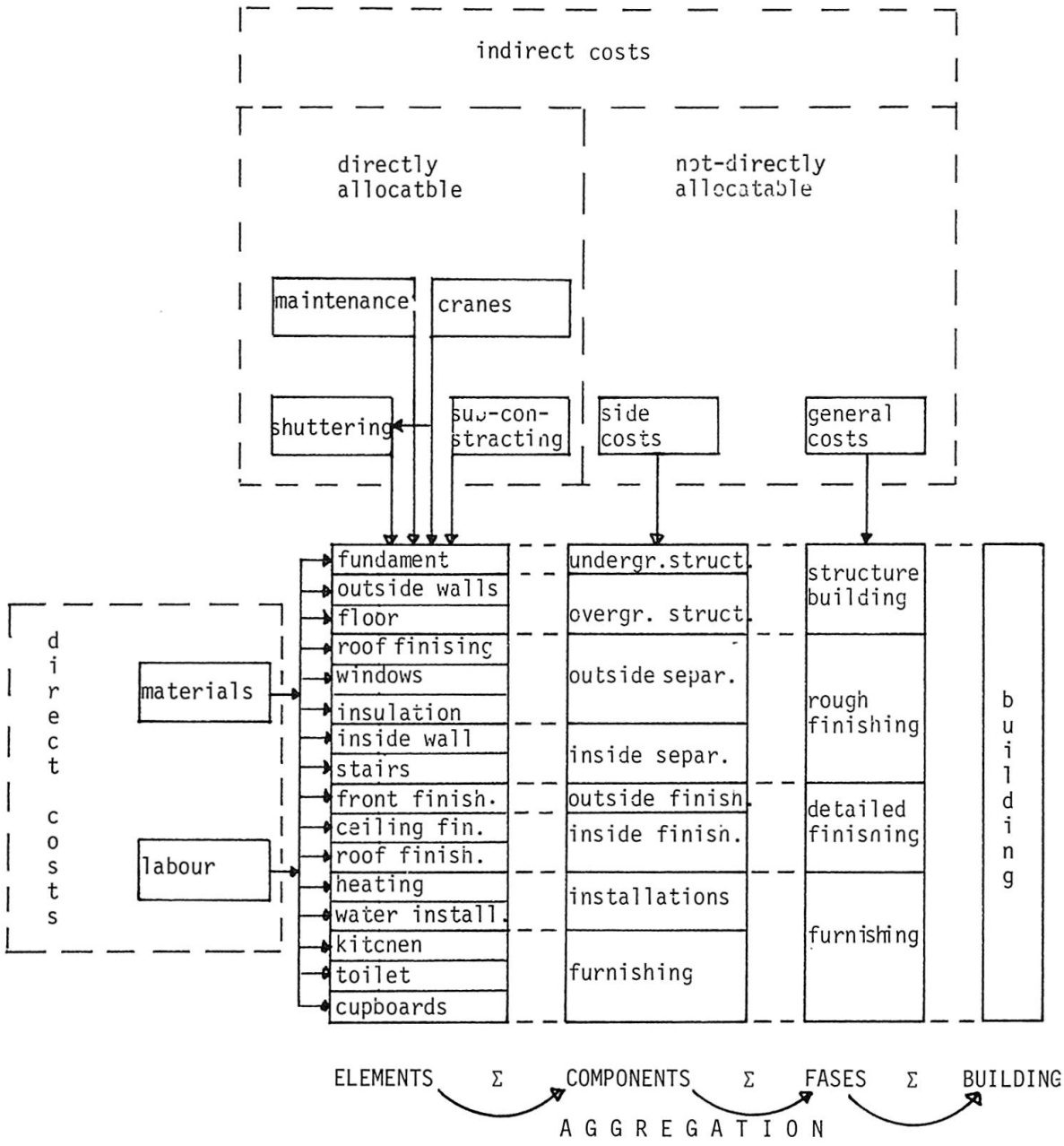

Diagram 3: Principle of a cost-allocation-scheme

3. THE EXPLOITATION PROCESS

3.1 Introduction

For government, the housing problem is mainly the insufficient amount of money available for investment in new building activities and in rehabilitation. In the long term, however, the costs of housing do not depend only on investment, but also on the period costs of housing: depreciation, interest, maintainance and energy. These costs are influenced considerably by the building process. Future costs should play an important role in decision-making during the design-and-construction process. As a consequence of this idea, houses have to be split up into parts with their own predictable period costs. These parts (components-in-use) can be chosen rather independently in the design period. Choices afterwards (rehabilitation) depend on the techniques used in constructing new buildings.

Dominant factors are the part of the limited national income available for housing and the variables in the indispensable cost-in-use analysis. The way in which period-costs are counted influences the matrix used in the design-and-construction process.

3.2 Period costs

As with every durable good, the desicion is taken at the moment of investment on the basis of future period costs. The period costs make it possible to earn back the initial investment, either as rent to be paid by the tenant, or the rent saved by the occupant owner of the house.
The period costs are not linearly related to the amount of money initially invested. The investment influences the depreciation-period, the frequency and costs maintainance and the costs of energy. A higher investment possible decreases maintainance and energy costs, but leads to increased interest. A costs-in-use analysis is needed for good decision making. For each investment, the depreciation costs and interest have to be counted. The utility for the occupant of a change in investment can be of two kinds. Increase of utility and an increase of the period costs, or unchanged utility and decreased period costs. Prediction of these effects is difficult but necessary.
The direct costs of investment together with the complementary costs partially fix the period costs. The period costs have to be compared with the utility got back in return. This comparison can lead to an increase or a decrease of the part of the yearly income spend on housing. The marginal utility of the last dollar spend on housing has to be compared with alternative spendings.

3.3 'Costs-in-use'

The choise of method for counting the costs-in-use may seem - like the choice of method of calculating depreciation - to be an economic problem. True, some rules given by the micro-economy have to be used, but filling in the variables is a technical problem.
Most - if not all - parts of a building need maintainance to keep it in condition to do the foreseen job. After some time, some parts have to be replaced, according to the wishes existing at the moment of decision. Maintainance and replacement have the same goal; they differ only in period, not in principal. Comparing costs of investment and costs of maintainance and replacement depends on the forecasting of technical variables. Since the oil-crisis - nearly ten years ago - the costs of energy used in a house have considerably increased. The part of the income it consumes is so large, that it is - even in the countries with a moderate climate -

worthwile to invest in better insulation. Government - at least in the Netherlands - stimulates investment in insulation by regulations in the case of new-construction, and subsidies for insulation in the case of existing houses.

It is strange to notice that government stimulates only a partial cost-in-use analysis. Since matural gas has a more direct and immediate influence upon the national budget the government feels responsible towards it. Maintainance and replacement seem not to be interesting until the moment politics comes into the picture. A lot of costs can be saved when government acts like business managers. In fact, when a firm invests in a building, future costs are a variable in the decision making-process. When individual investers in housing are not interested in future costs, and government feels itself responsible for this merit good, it should stimulate them to take into account all variables showing up in a cost-in-use analysis.

3.4 Depreciation

The investment in a house is an amount of money not to be neglected. The period in which the investment can be used is so long, that the average sum per year is rather low. It is low compared to interest and other costs like maintainance and energy. The costs of depreciation are, however, underestimated. The under-estimation has three causes:

- depreciation is neglected because of increasing houseprices;
- period costs are based on historical costprice;
- lifetime of the investment is overestimated.

Private investments in houses were in the last decades attractive more because of the increase in house prices, rather than because of the return on investment from rents. Depreciation was used to calculate the fiscal income, but the amount of depreciation was not the result of a fundamental study. Government decides whether depreciation should be done on the basis of the historical costprice or on the present value. The choice of the basis is of utmost importance for counting rents. It is in fact a political problem with important macro-economical consequences.

In combining the construction and exploitation process the third argument in the underestimation of period costs is most interesting. This overestimation of life-time is a technical problem, not economic. It is technical in the sense that one has to foresee the moment when the house can no longer give the serives it was build for without important investments in maintainance and/or replacements. The moment at which it is cheaper to build a new house than to rehabilitate the old one, the economical lifetime of the latter has passed away.
In reality, however, this decision is a range of decisions which depend on various components of the house with their own lifetimes: a building is a complex durable (consumption) good.

3.5 The house as a complex durable good

The lifetime of a house cannot be estimated for the building as an entity. The structure of the house in itself can not be used separately; only when it is filled in with inside walls, kitchen etc. can it be used. The lifetime of the structure and the finishing and furnishing units vary. The structure can be filled up with different combinations of finishing and furnishing elements. So

it is clear, that it is not possible to speak of one investment in a house on which depreciation and interest calculation has to be based. The decision about investment and replacement has to be based on the lifetimes of the elements [1].

It is argued that the elements of a house are more or less independent. This does not mean however, that they are also technically independent. An element whose lifetime has expired can sometimes not be replaced without replacing another element that can still be used. The cheapest solution depends on the costs of the different systems and the 'waste' of capital when a still useful element has to be replaced. Technically, it will be possible to make elements independently replacable; economically, it will not be useful for all elements.

It is usual to regard a house as a durable good. In fact, a house is a combination of a number of durable goods. These durable goods have different lifetimes; in combination they form the house. Combination of elements with the same lifetimes gives a component which forms an entity in the construction new buildings and at the moment of replacement. The combinations do not depend only on the technically possible lifetimes, but also on the usefulness for the user in every period of their lifetimes.

3.6 Components in use

For many parts of the furnishing and finishing of a house, it will be possible to give them a very long technical lifetime. In reality, however, it is not only the technical lifetime which is the most important variable, but the taste of the user. Elements can be useless because of changing fashion. The lifetime of an element is determined by the technical lifetime or the economic lifetime, whichever is shorter.
The shortest of the technical lifetimes and the economic lifetimes defines the lifetime of an element. Prediction of the lifetime is never exact. The influence of the weather, use and fashion is always unsure, which does not mean that the prediction has not to be made.

Another aspect is that the lifetime of all elements can be different. When every element is used until its last day, this will cause a continues process of replacing and rehabilitation. For economic reasons, the number of rehabilitations - a combination of replacements and maintainance - has to be limited. Combinations of elements have to be made in a way that only every 10 or 15 years need one decide on how to rehabilitate. Within such a period only maintainance will be necessary.

The consequence of limiting the number of rehabilitations will not be that one is sure in advance about what will happen after e.g. 15 years. It will not always be necessary to replace everything whose economical lifetime had been predicted to expire. Sometimes, some elements will not be replaced, in some other cases identical replacement and sometimes replacement by technically advanced elements will be done. After replacement costs will be reduced, be constant or be increased, respectively.

For example, after 15 years the following replacements can be done:

- technically necessary:
  - cover of the flat roof
  - central heating;

- economically necessary:
  - kitchen furniture,
  - wall finishing on the ground floor.

Replacements of the above mentioned parts of the house can be done rather independently. They are, however, economically connected. Investment in the insulation of the flat roof influences the investment in the central heating. Likewise kitchen furniture and wall finishing can be interrelated. One cannot decide on individual elements. Decisions have to be made about interrelated elements. Interrelated elements are called 'components-in-use'. Likewise, elements interrelated in the design-and-construction process are called 'construction'-components.

3.7 Diagram of the allocation of using costs

Having concluded that decisions about construction or rehabilitation have to be made on components level, we have to summarise all costs that influence the decision. These are the above mentioned period costs: interest, depreciation, maintainance and energy. For every component these costs have to be calculated. When for every component the invested amount and the lifetime is known, the load of interest and depreciation can be calculated. The best way seems to be the annuity: a constant amount of money in every year of the lifetime period including depreciation and interest. This will be realistic when the usefulness of a component is constant during its lifetime period.

In the same way, costs of maintainance can be spread over the lifetime. Energy costs can be estimated too; together they are the complementary costs. All estimations will be influenced by price increases; energy more than the others. The first calculation will be made in constant prices. The principle of the calculation is shown in diagram 4.

The direct costs and a part of the indirect costs are collected in the elements, as the construction-costs-allocation-diagram shows. The remaining part of the indirect costs will be allocated as a rise in the element costs relative to the element costs. Further research will possible lead to allocation of these indirect costs in a more proper way. Since the remaining part of the indirect costs is only a few percent, the miscalculation in the period costs of the components will be rather small.

The annuity of the investment costs and the complementary costs can now be calculated. Together they show the period costs per component. Aggregated, they yield the period costs of the house for a period between two rehabilitations.

For some components, the period costs will remain unchanged over a long period; others will change after every rehabilitation. The kind of rehabilitation influences the change in period costs of some components and of the house.

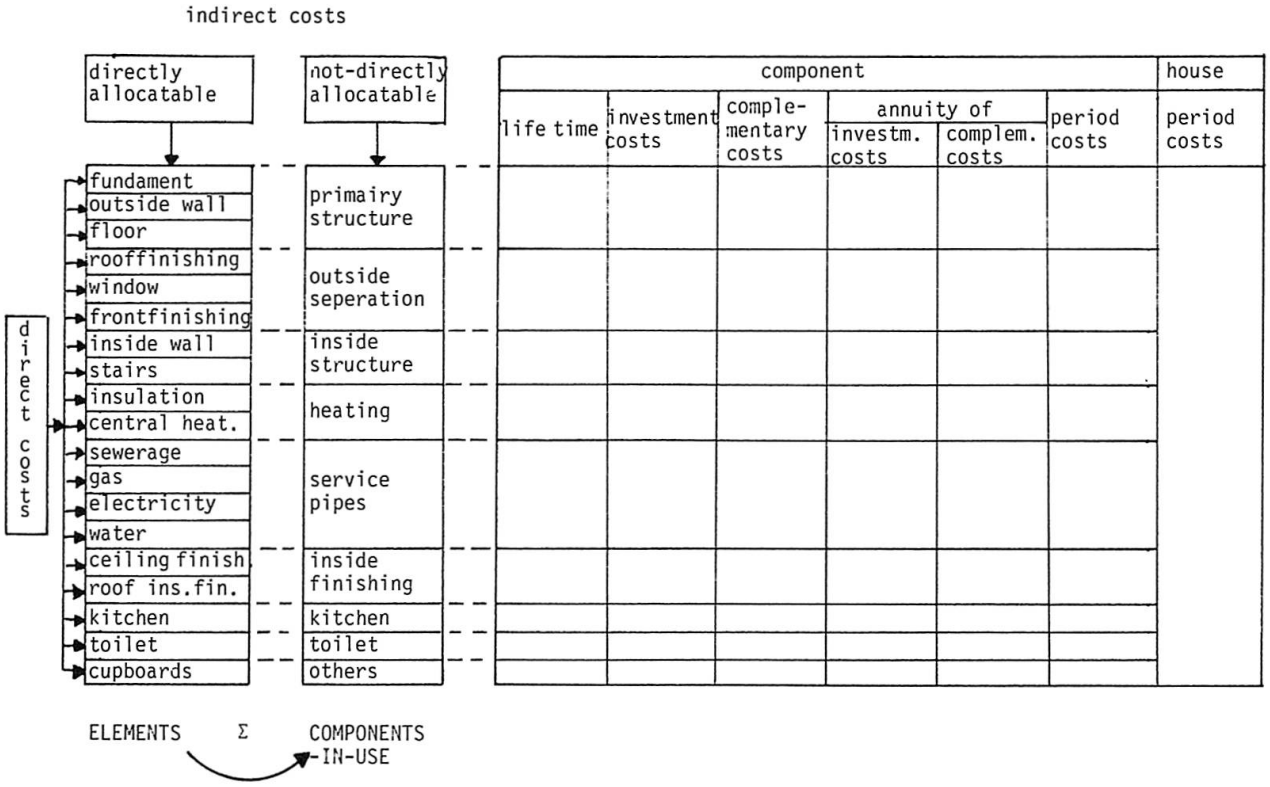

Diagram 4: Principle of a diagram of allocation of using costs

4. A MATRIX OF COMPONENTS

4.1 Introduction

In parts 2 and 3 it has been shown that, on the basis of elements - to be recognised in a building - and components which are groups of elements, the costs of construction and of exploitation can be calculated. The two diagrams of cost allocation and cost calculation have to be united into one diagram. This is necessary because for the design process in new building, information about the elements in the exploitation phase is needed. Moreover, the ultimate users - new ones or the present occupants in the case of rehabilitation - want to know which financial consequences they have to bear when a change in the design or construction process is introduced. Also when government decides it is necessary to know the desires of the future users.

For maintainance and future rehabilitations, present decisions are of utmost importance.

For every element of a building, it is necessary to know its role, in the exploitation process - in the long term - as well as in the construction process. Then every participant in the housing process can get the necessary information.

4.2 Matrix of components

Cost allocation to get the construction price and the exploitation price is based on the information accumulated in the elements which together form the house. In the construction process costs are allocated to the elements and partly to the components-in-construction and construction phases to get the total costs by aggregation. In the exploitation process, elements are the basis for cost calculation. Since elements are not used separately, components-in-use are defined, and new decisions and cost calculation can be based on these. The inter-relating of these two procedures - necessary for cost communication - can be done by creating a matrix with on one side the components-in-construction and on the other the components-in-use.

A matrix or this sort has been introduced in the past as the CI/SfB-matrix. This system is being adapted in Great Britain and The Netherlands for use in house-building. This matrix however cannot be used for allocation of indirect costs, and is created only for the construction process. A matrix for more kinds of use will be totally new. Only some elements can be recognised in the existing CI/SfB-matrix.

All elements of a house have to be combined into components in two ways. Combining them into components-in-use leads to period costs as described. Combining them into components-in-construction and construction-phases gives the construction costs.

The problem is to give all elements (diagram 5 only illustrates the most important of these) in such a way that for each construction system the useful components will be found. For instance, whether the function of an outside wall is defined, carrying or not-carrying depends on the system - classical or prefab. The wall's being carrying or not determines the component it belongs to.

The elements connect the components-in-use and the components and phases in the construction process.

4.3 Consequences for users and governments

Future occupants of houses establish the ultimate demand for houses. Partly the role of determing demand has been taken over by government, though not to the same extent in every country. When government influences the demand, it should have enough information on which to base its decision. The only one who can give this information is the collective of future house occupants. However the more government influences demand - by subsidies and taxes - the less clear it is to the users what they can ask for and for what price.

This can only be converted to real prices by calculating exactly the exploitation costs of houses and making them clear to the occupants and decision makers. This does not mean that one should immediately stop subsidizing occupants or houses; it is only to show what the real costs of housing are[2]. A more slowly growing or even decreasing national income can mean that one will build more cheaply and/or will increase rents. The decision will not only be taken on basis of the invest-ment costs at the given moment but also - more importantly - on the exploitation costs in the future.

MATRIX-OF-COMPONENTS

component-in-use	component-in-use: investment costs	lifetime	complementary costs	annuity of: investment costs	annuity of: complementary costs	period costs	house: period costs
primary structure							
outside separation							
inside structure							
heating							
service pipes							
inside finising							
kitchen							
bathroom							
toilet							
other							

components-in-constr.	underground structure	overground structure	outside separation	inside separation	outside finishing	inside finishing	instal-lations	furnishing
construction phases	structure building		rough finishing		detailed finishing		furnishing	
construction								

	underground structure	overground structure	outside separation	inside separation	outside finishing	inside finishing	instal-lations	furnishing
primary structure	foundation	carrying outside walls carrying inside walls floors						
outside separation		roof construction	roof outside finishing not-carrying outside walls windows outside doors roof aperture		front-finish.			
inside structure				not-carrying inside walls stairs				
heating			insulation materials				central heating	
service pipes							sewerage gas electricity water	
inside finising				inside doors		inside wall ceiling finish stair finish. roof finish. floor finish.		
kitchen								kitchen
bathroom								bathroom
toilet								toilet
other								other sanitary cupboards

INVESTMENT

Diagram 5: Confrontation of investment and exploitation costs in a matrix-of-components.

4.4 Consequences for design-and-construction

As a consequence of changing demand - in quantity and in character - supply will likewise have to take changes in account.
When the occupant knows that in the future he will be more liable than at the present moment to pay the real price, he will want to know in advance the real exploitation costs consequent to his wishes. In the phase of formulating the list of desires, exploitation costs should be clear. For each possible component-in-use the cost-consequences must be compared to other possibilities.

The architect will be able to give - when the most important cost factors of the components-in-use are known - not only the investment consequences of his design, but the exploitation cost consequences too. Alternatives in design and construction can thus be compared in a realistic manner.

Consequences for the constructor would seem to be rather unimportant; however this is in fact not true. When demands change, because demands are concentrated around components-in-use and not around the house as an entity, the construction industry has to change too. For most of the elements or components, the supplier has to give information about lifetime, maintainance costs and the possibility of replacement without replacing many other elements. The construction process will have to be adapted in such a way that components which can be used in many different combinations will be supplied.

5. CONCLUSION

When government regards housing not only as a micro-economic problem, and the design-and-construction industry concentrates on supplying housing services instead of houses, the housing problem will change drasticaly in character. Demands can become clearer, with the consequence of a better adaptation of the supply. Housing can be cheaper, or better at the same price.
Confrontation of supply and demand, needs a combination of construction and exploitation costs. The use of the presented matrix - filled up with realistic figures - is the first and most important step in the proper direction.

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