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Cost comparison and productivity study of basic apartment maintenance systems: literature survey and field study

Osmo Ville Kettunen
University of Windsor

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OF AUTHOR/NOM DE L'AUTEUR: Osmo Ville Kettunen

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SIGNED/SIGNÉ: April 15, 1997

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FINLAND
COST COMPARISON AND PRODUCTIVITY STUDY OF BASIC APARTMENT MAINTENANCE SYSTEMS;
LITERATURE SURVEY AND FIELD STUDY

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES THROUGH THE DEPARTMENT OF INDUSTRIAL ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF APPLIED SCIENCE AT THE UNIVERSITY OF WINDSOR

BY

OSMO VILLE KETTUNEN

UNIVERSITY OF WINDSOR
WINDSOR, ONTARIO, CANADA

August 1977
This thesis applies the techniques of industrial plant maintenance to apartment building maintenance. A statistical field study was carried out in Finland. It includes 1839 apartment building companies from 12 cities and randomly selected localities. The companies have 86,214 apartments.

For the comparisons of productivity in technical maintenance of apartments a model was developed. The total productivity, \( P_T \), is given as \( P_T = \frac{O}{L+C+R+Q} \), where output, \( O \), indicates the total volume of buildings maintained; \( L \) indicates total input of labor work, \( C \) is total capital investments; \( R \) is total input of material; and \( Q \) is annual input cost for subcontractors.

Traditional and centralized maintenance was compared. The maintenance systems were studied in five phases; \( P_0 \) method when traditional systems used, \( P_I \) when buildings connected to district heating, \( P_{II} \) when centralized in some degree, \( P_{III} \) when also repair work and other service works are specialized, and \( P_{IV} \) when computerized building automation utilized. The total productivity in the five phases is when measured with indices \( P_T (P_0) = 100 \), \( P_T (P_I) = 110 \), \( P_T (P_{II}) = 135 \), \( P_T (P_{III}) = 145 \), and \( P_T (P_{IV}) = 150 \). The actual value of \( P_T \) for instance in Phase 0 is \( P_T (P_0) = 0,10 \) building-m\(^3\)/Finnish mark. Correspondingly, the costs of technical apartment maintenance, \( C \), in the five phases decline as follows when measured with indices \( C_0 = 100 \), \( C_I = 87 \), \( C_{II} = 78 \), \( C_{III} = 74 \), and \( C_{IV} = 68 \); the real costs for instance in Phase 0 is 9:96 Finnish marks/building cubic meter/year. The increase in the maintenance productivity is highest between the Phase I and II; when centralized maintenance has been introduced.

The total savings in Finland by centralizing the apartment building maintenance could be 122 million Finnish marks.
if the system would be introduced in 84 urban localities. The saving in the housing costs of separate apartments in 760 Finnish marks/apartment/year.

The paper includes a special survey over apartment building maintenance in Finland, England, West Germany, Sweden, and Japan. Besides that there is an extensive literature study about industrial plant maintenance pertaining to apartment maintenance.

The advice and friendship of my colleagues have been valuable in this research work.

This research project is financed by the Government of Housing in Finland. The experimental part of the research work has been done at the Technical Research Center of Finland, Building Laboratory. The very numerous literature references have been collected by the Technical Information Center of Finland, Helsinki.

I wish to extend my appreciation to all building maintenance organizations and companies in Canada, U.S.A., Sweden, Poland, Czechoslovakia and Finland that have given their expert knowledge during my visits.

I am grateful for the financial support provided by the Rotary Foundation of Rotary International, Evanston, Illinois, U.S.A.

Oulu, Finland
August 8, 1977

Osmo Ville Kettunen
ACKNOWLEDGEMENTS

I express my deep appreciation to Dr. A. Raouf for his encouragement, suggestions and the considerable time he spent in seeing this research project to conclusion.

My gratitude is also expressed to the other members of the graduate committee, Professor A. Danish, Dr. D. Kochar, Dr. G. Monforton and Dr. C. MacInnis for their help and encouragement.

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Osmo Ville Kettunen
### List of terms used in the text

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM3</td>
<td>Total volume of buildings in a building company measured with cubic meters (m³).</td>
</tr>
<tr>
<td>BM2</td>
<td>Total brutto area of floors in a building company measured with square meters (m²): included are apartments, stair cases, basement, etc.</td>
</tr>
<tr>
<td>LM2</td>
<td>Total area of all apartments or other dwellings in a building company measured with square meters (m²).</td>
</tr>
<tr>
<td>Fmk/BM3</td>
<td>Unit cost Finnish mark per cubic meter of building</td>
</tr>
<tr>
<td>Fmk/LM2</td>
<td>Unit cost Finnish mark per apartment square meter</td>
</tr>
<tr>
<td>n</td>
<td>Conversion coefficient to change the unit cost Fmk/LM2 to Fmk/BM3; based on the technical characteristics of apartment buildings in Finland (Statistics of Government of Housing, Helsinki).</td>
</tr>
<tr>
<td>ε</td>
<td>Conversion coefficient to change the prices in 1975 to the prices in 1976 (base year of study). = 1.09</td>
</tr>
</tbody>
</table>

#### Mathematical formulas:

- **Capital recovery factor**
  \[(A/P, i\%, N) = \left(\frac{i(1+i)^N}{(1+i)^N-1}\right)\]

- **Sinking fund factor**
  \[(A/F, i\%, N) = \left(\frac{i}{(1+i)^N-1}\right)\]

- **Present worth factor**
  \[(P/F, i\%, N) = (1+i)^{-N}\]

- **Series present worth factor**
  \[(P/A, i\%, N) = \left(\frac{(1+i)^N-1}{i(1+i)^N}\right)\]

- **Arithmetic gradient to uniform series**
  \[(A/g, i\%, N) = \left(\frac{1}{i} - \frac{N}{i(1+i)^N-1}\right)\]

- **Arithmetic gradient to present worth**
  \[(P/G, i\%, N) = \frac{1}{i} \left(\frac{(1+i)^N-1}{i} - N\right) \left(\frac{1}{(1+i)^N}\right)\]
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The methods of maintenance works and service in apartment buildings have developed during the last 70 years. Methods are, in general, manual and old fashioned compared with the possibilities available. The influence of labor unions and their long traditions seem to suggest to some degree the reorganization of maintenance operations. Separate maintenance groups are often small and are not economically feasible. Traditional maintenance methods are ineffective, expensive and labour demanding.

It is known that there are at least 400 different kinds of work in the maintenance of apartment buildings but, in general, the exact character of these works and the probabilistic distribution of their occurrence is unclear. Most of the maintenance works are manual but in the larger maintenance groups the use of machines, mechanized equipment and automation is relatively common.
I. INTRODUCTION

1. THE APARTMENT BUILDING MAINTENANCE SYSTEM

For understanding of this paper the apartment building maintenance is defined as follows:

Apartement building maintenance refers to all the activities which assist in keeping buildings and other facilities, areas, machinery and equipments connected with them, in good shape, and in guaranteeing the continuous functioning of the buildings without any losses, adequate residential well-being, and other services required from the building.

This definition has not been previously used but it is close to that of the German DIN Maintenance Committee definition for maintenance in general.

The methods of maintenance works and service in apartment buildings have developed during the last 70 years. Methods are, in general, manual and old fashioned compared with the possibilities available. The influence of labor unions and their long traditions seem to suggest to some degree the reorganization of maintenance operations. Separate maintenance groups are often small and are not economically feasible. Traditional maintenance methods are ineffective, expensive and labor demanding.

It is known that there are at least 400 different kinds of work in the maintenance of apartment buildings but, in general, the exact character of these works and the probabilistic distribution of their occurrence is unclear. Most of the maintenance works are manual but in the larger maintenance groups the use of machines, mechanized equipment and automation is relatively common.
The aim of a single maintenance group is the lowest possible unit cost of maintenance and a reasonable standard of maintenance service. This determines the arrangements of maintenance today. However, the national economic aspects seem to be very strong and may become the dominant factors. It is possible to introduce larger and more advanced systems and automation into maintenance operations. In practice, the arrangement of maintenance operations in each maintenance group is connected with factors peculiar to the locality and immediate neighbourhood of the buildings. The surrounding maintenance load of each maintenance group has a fundamental importance for systems' planning. Hence, both the overall areal maintenance planning and separate maintenance groups' operational planning are mainly a part of larger urban techno-economic planning.

In many countries today, apartment building maintenance is being mechanized and to some degree automated. Here the mechanization is the replacement of pure manual power in outside cleaning and in some repair works. The building automation has meant the introduction of computers as an on-line bases in the control of machines, measurements and other trivial continuous operations. Compared with the industrial automation and mechanization the apartment building maintenance is still manual to a high degree.

In Fig. 1.1 there are shown three control loops of building maintenance process:

(a) **Short range loop** which includes operations having characteristics of alarms and warnings. The separate activities are relatively small and are connected often to machines, equipment, etc.

For short range loop operation there is often a special warning control system, sometimes based on computerized building automation.
(b) Normal range loop including routine maintenance control, continuous repairs, etc.

(c) Long range loop including the management and analysis of maintenance with a longer planning horizon for maintenance development.

Most of the repair works belong to the normal range loop. However, the activities in the short range loop have to be taken very strictly into consideration both in the arrangement of repair organization and in the planning of control facilities and equipment.

Fig. 1.2 shows the principle of feedback control in automated building maintenance process. The traditional maintenance process (Fig. 1.1) is very common, especially among small building companies, in any country. The closed-loop maintenance can usually be found in large building companies.

Fig. 1.3 shows the development of apartment building maintenance. The characterization is simplified and generalized; in various countries, especially between the industrialized and the developing countries, there are considerable differences in the development phases. The differences in development phases are significant even inside separate countries, usually depending on the size of the locality: in big cities the apartment maintenance systems are more advanced than in small towns.

In Tableau 1.1 there are given the average annual maintenance costs and use of resources in average apartment in 1976. The median annual running costs of an apartment with an area of 70 m² is 4 000 Fmk. The variation in costs depends on the type and age of the building, the level of housing and maintenance services, and the ownership arrangement of apartments. The costs in residential building companies are, in general, higher than in apartment-owning companies. Fig. 1.4 shows the distribution on annual costs in an average Finnish maintenance group in 1975.
Figure 1.1

Control loop relations in apartment building maintenance process.
Figure 1.2
Principle of feedback system in building maintenance process, when computer is utilized.
Figure 1.3
Development of apartment building maintenance in Finland from 1920 to 1977.
Figure 1.4
Distribution of the annual technical maintenance costs of apartment buildings in Finland in 1975. Apartment-owning companies, subsidized by government loans (Asuntohallitus). Capital costs excluded (Government of Housing, Finland).
### Urbanization

<table>
<thead>
<tr>
<th>Category</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating energy 1)</td>
<td>85 kWh/m³</td>
</tr>
<tr>
<td>Electricity</td>
<td>14 kWh/m³</td>
</tr>
<tr>
<td>Water consumption 2)</td>
<td>0.8 water/m³</td>
</tr>
<tr>
<td>Use of manpower 2)</td>
<td>0.22 manhours/m³</td>
</tr>
<tr>
<td>Annual garbage amount 3)</td>
<td>4.5 kg/m³</td>
</tr>
<tr>
<td>Other costs outside 3)</td>
<td>50 Fmk/m³</td>
</tr>
</tbody>
</table>

1) Equals the same as 9 liters of heating oil per m³.  
2) One manyear has 1 800 manhours.  
3) Including taxes, land lease, insurances for property, material for repairs and cleaning.  
4) Exchange rate US$ = 4 Fmk.

In Finland (Fig. 1.6), especially in the 1960's and 1970's, large homogeneous areas of blocks of flats have been built. Table 1.1 shows the use of resources per building-m³ in an average apartment building in Finland in 1977. Hypothetical example based on cost analysis of this study. Capital costs excluded. (Estimation by author).

An urban area is a system of interacting industries, housing, and people (Rasch and Kettunen, 1977; Miles, 1973; Forrester, 1969). The general model for a city or an urban area is rather complex, and often the theoretical models have been impractical and inadequate (Aben, 1971; Lee, 1975).
URBANIZATION

According to the population of the world in 1976 the number of housing units may be estimated to be some 600 million dwellings. A fair proportion of these units is apartments located in dense building areas of industrialized urban centers. In industrialized countries about 70 percent of the people are living in urban areas, Fig. 1.5. The main reason for the very fast urbanization process is the population growth and industrialization. The annual population growth of 2.5 to 3.0 percent in the developing countries makes the urbanization process qualitatively different than that, for instance, in Europe in the nineteenth century with the population growth of 0.5 percent. Besides the population growth, about 200 million people have moved from rural areas to the cities.

In Finland (Fig. 1.6), especially in the 1960's and 1970's, large homogeneous areas of blocks of flats have been built, Fig. 1.7. There has been a drastic increase in the apartment building production after 1950. The proportion of apartments in all homes increases when the size of locality grows (Fig. 1.7b). Also the design of apartment building blocks has changed considerably. Fig. 1.8 shows as a scheme the development of apartment building block in Finland in 1800...1970. The blocks of 1940's and 1950's are common in the surroundings of the city-center areas, the blocks of 1960's and 1970's are usual in new suburbs. Especially the developing of large and uniform apartment building areas has made necessary a rearrangement of maintenance operations in a new and more effective way.

An urban area is a system of interacting industries, housing, and people (Raouf and Kettunen, 1977; Miles, 1973; Forrester, 1969). The general model for a city or an urban area is rather complex, and often the theoretical models have been impractical and inadequate (Aben, 1971; Lee, 1975).
Alonso (1971) and Catanese (1972) have discussions about the urban magnitude. Public expenditures per capita increase when the population size class of the urban area and also the population density increase. At the same time the technical and organizational complexity of building maintenance and other related urban operations grow drastically with the increase of urban size. A situation is often reached in which the capacity of some of the existing urban services is no longer adequate. In community building this is called threshold cost (Kozlowski, 1972).

Figure 1.2
a) Growth of world population

<table>
<thead>
<tr>
<th>Million people</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
</tr>
<tr>
<td>500</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>50</td>
</tr>
<tr>
<td>10</td>
</tr>
</tbody>
</table>

Population in cities over 100,000 people

Year

b) Urbanization of population in Germany, USA, Sweden and Japan

<table>
<thead>
<tr>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1910</td>
</tr>
<tr>
<td>1930</td>
</tr>
<tr>
<td>1950</td>
</tr>
<tr>
<td>1970</td>
</tr>
</tbody>
</table>

Germany
USA
Sweden
Japan

c) Variation in percent of urban population in industrialized countries

Figure 1.5
Figure 1.6
Population growth in Finland in 1750...1976 (Statistical Yearbook of Finland, 1975).

Figure 1.7
a) Number of apartment buildings in Finland built in different years.
b) Proportion of one-family-houses in the total home production as a function of locality size in Finland in 1971 (Kettunen, 1975).
Figure 1.7
a) Number of apartment buildings in Finland built in different years.

b) Proportion of one-family-houses in the total home production as a function of locality size in Finland in 1971 (Kettunen, 1975).
Figure 1.8

Scheme of blocks of apartment buildings built in different years.
Figure 1.9
Large apartment maintenance area including several maintenance groups. There are 180 buildings in the maintenance area. The suburb has been built in 1960's. Tensta, Sweden.

Figure 1.10
Suburban areas built in 1960's and 1970's. The maintenance areas include several maintenance groups. Jakomäki (left) and Matinkylä (right), Helsinki, Finland. The buildings belong to the Set A in the experimental study.
SOME DEFINITIONS OF APARTMENT BUILDING MAINTENANCE

The following definitions apply in this paper:

An Apartment is a space with 1 to 4 and sometimes more rooms, kitchen or kitchenette, bathroom or toilet and store room. Apartments are centrally heated; there is electricity and sometimes gas and air conditioning. Apartments are unfurnished. The average size of an apartment, \( s \), is 70 m\(^2\); in Scandinavian countries, the area range is \( 30 m^2 \leq s \leq 95 m^2 \), seldom more.

The people living in apartments are called tenants. Tenants can own or rent their apartments. If the tenants own the apartments, there is a special apartment-owning stock company: tenants are responsible of inside repairs of their apartments. If the tenants do not own their apartments, there is a tenant building company: the company is responsible for all repairs. These building company types are common in Finland. In other Scandinavian countries the apartment co-operations and dwelling-associations are common. They have characteristics of the tenant building company.

Service Firm is an organization which does maintenance

An Apartment Building has usually 20 to 40 apartments, and sometimes up to 200...350 apartments. Buildings have at least three stories, often 5, 7, 9 or 12 stories.

A Maintenance Group (Fig. 1.11) is the smallest independently operating unit in apartment maintenance. It includes 1 to 1,000 buildings with their outside areas. Maintenance group is constituted of one or several independent building companies. For instance, in Finland maintenance groups have usually 3 buildings and 50 apartments, the large ones up to 4,000 apartments. In Sweden they may have often 5,000 apartments, and in Singapore 70,000 apartments.

A Maintenance Area includes one or several maintenance groups which are in partial or total maintenance co-operations with each other.
Maintenance Load is the total amount of maintenance groups or buildings in a certain area (e.g., city or suburb), that have to be maintained by various methods.

Potential Urban Operations include arrangements of items in densely populated urban area. Here the interest is in urban operations which have a certain connection with apartment maintenance (e.g., fire department, police).

Common Area is the space in an apartment building, where apartments are excluded. Common area includes, for instance, staircases, lounges, sauna baths, swimming pools, store areas, parking garages, etc.

Foreman is supervisor of practical maintenance works.

Technical Space is the part of common area, which is not in common use: heating systems, ventilation, repair room, etc.

practical maintenance works working with other labourers.

Outside Area is the area around the buildings of maintenance group that must be maintained.

Inside Area is the area in the buildings that must be maintained.

Service Firm is an organization which does maintenance works for a certain remuneration.

Service Center is the space in the maintenance group, in which the maintenance works, the resources of service and servicemen are centralized.

Administrative Center is the space in the maintenance group in which the administrative works, personnel and tenant service are centralized. Service and administrative center have often been connected.

One maintenance group has the following workers with their personnel definitions, Fig. 1.12 and Fig. 1.13.
Manager, who takes care of general administration and operations. In a small maintenance group he is also the foreman of workers, and often called superintendent.

Assistant resident manager, who is under the direct supervision of the resident manager and takes care of general administration, plant operations and maintenance, usually in a large maintenance group.

Operation Chief is responsible for maintaining and operating all mechanical equipment and usually he is the foreman of repairmen.

Foreman is supervisor of practical maintenance works.

Responsible leading worker is assistant supervisor of practical maintenance works working with other labourers.

Custodial Supervisor directly supervises the cleaning crew and the grounds personnel.

Groundsman takes care of outside areas of the maintenance group.

Maintenance Men, Servicemen, Repair Men, Custodians take care of special separate maintenance operation.

Janitor (caretaker) takes care of usual maintenance operations with no special characteristics. Janitor is common in small and traditionally operated maintenance groups.

The usual operating maintenance personnel of medium large maintenance groups includes manager, operations chief, custodial supervisor, maintenance men, custodians and groundsmen. Small maintenance groups usually have only manager, janitor and custodian; often they work on a part-time basis.
Figures 1.12 and 1.13 show the organization in traditional and centralized, enlarged maintenance group. When the size of maintenance group grows there will be a supporting staff maintenance management, and more personnel in repair works.

Objects

- Outside areas
  - Inside areas
    - Administration and management
    - Maintaining maintenance facilities and resources
    - Other resources
    - Tenants service
    - Finance, book-keeping and rent control
    - General management
    - Service station
    - Remote control equipment
    - Material
    - Energy
    - Capital
- Paved areas
  - Parking lots
  - Driveways
  - Other ways
  - Common spaces
- Lawns
- Natural ground
- Recreational areas
- Garbage disposal facilities
- Snow removal
- Storages
- Areas for wash, etc.

Figure 1.11
Functions of a maintenance group.
Figure 1.11
Functions of a maintenance group.
Figure 1.12
Principles of organizations in traditional and centralized, enlarged maintenance groups.

Figure 1.13
Organization scheme for traditional maintenance group and centralized medium large maintenance group.
Traditional organization

Manager (part time)

Janitor
- takes care of outside cleaning, repair and other technical works (usually part-time)

Custodian
- takes care of inside cleaning (usually part-time)

Organization scheme of medium large maintenance group with 4,000 apartments

Manager
- assistant manager
- administrative personnel

Operation chief

Foreman

Responsible worker

Responsible worker

Responsible worker

Custodial supervisor

Office chief

Heating group

Maintenance

Groundsmen

Custodians

Personnel for tenant service

Figure 1.13
Organization scheme for traditional maintenance group and centralized medium large maintenance group.
PURPOSE AND OBJECTIVES OF THE STUDY

The first general aim of this research work was to study the productivity of building maintenance, the real maintenance operations by servicemen and the basic characteristics of maintenance arrangement in various maintenance groups.

Under the progress of this study, however, the client of research work (Government of Housing, Finland) wanted to direct the study, after the preliminary but reliably direction showing results, to the cost comparison and investigation of total productivity of basic maintenance methods.

The objectives of the study were given as follows:

(1) Study the total productivity of building maintenance for the principal apartment maintenance models and especially between the traditional and centralized maintenance system.
(2) Investigate the differences in the technical maintenance costs of basic maintenance methods.
(3) The effects of various heating systems in the apartment maintenance.
(4) To have an investigation over the remote control of apartment buildings.
(5) Extra costs of equipment and facilities when introducing centralized and rationalized apartment maintenance model in comparison with the traditional maintenance model.
(6) To have a review and literature study about building maintenance in other countries.

Thus the emphasis of objectives has dominantly moved to the large-scale local and national economic aspects of apartment building maintenance.
A subobjective of the study was to investigate the possibilities of using the methods of industrial plant maintenance to apartment maintenance.

The purpose of the study is to provide the decisionmakers in the housing area in Finland relevant information for the present and future development of apartment building maintenance. The general goal was to define whether the overall centralization of apartment building maintenance is profitable or not.
II: LITERATURE REVIEW

1. RESEARCH WORK ABOUT APARTMENT BUILDING MAINTENANCE SYSTEM

For this research work over 700 publications and papers\(^1\) about apartment building maintenance, and topics that are closely connected to apartment maintenance, were studied in 1975 to 1977. The literature study includes published and also unpublished material about apartment maintenance from fourteen countries.

Raouf and Kettunen (1976, 1977a) have discussed the general principles of apartment maintenance arrangement. A special attention has been given to the urban operations which are closely connected to building management and maintenance. In Canada, the Ontario Housing Government and Cadillac Fairview (Toronto, Ontario) have made efforts in this area.

In the Finnish government committee paper (Komiteammistintö, 1969) there is a short review of how to calculate the workers' input in traditional maintenance works. In a statistical research paper Kettunen (1975) has examined some fundamental areas in the maintenance of apartment buildings and the arrangement of basic operations. Kettunen has constructed a mathematical model for the functional size and area of maintenance group by using statistical multivariate methods.

The fundamental technical or work study aspects of apartment building maintenance have been discussed in manuals:

\(^1\) The literature references and other information is collected by the Technical Information Center at the Technical Research Center of Finland, and by the Industrial Attaches of Finland in Japan, England, Netherlands, West Germany, and the U.S.A.
for separate maintenance organizations. The literature or research papers of this type for general use do not exist at all. Even the number of apartment maintenance manuals and handbooks is rather low.

Usually the manuals are unpublished and intended only to the use of a single maintenance organization. The manuals are published by apartment maintenance organizations that have nationwide operations and which are economically feasible for planning of maintenance. In Sweden there are two apartment maintenance organizations (Hyresgästernas Riksförbund and Sveriges Allmännyttiga Bostandsföreningen). Both of them have their own manuals. In the USA Glassman (1974) has published a handbook for small maintenance groups concerning practical and general maintenance works. In the USA the National Association of Home Builders (Washington D.C.), and in Canada the Ontario Housing Government and Cadillac Fairview (Toronto, Ontario) have manuals of apartment maintenance. In general, they are concentrated in the management aspects of apartment building maintenance and the general arrangement of organizations and operations.

Systematized methods and operations measurement have not been adopted to building maintenance in research reports.

2. TERMS USED IN THE GENERAL MAINTENANCE AND IN THE APARTMENT BUILDING MAINTENANCE

In literature and theoretical studies the apartment building maintenance should be connected with the more general industrial plant maintenance. However, there is not any discussion about the maintenance terminology connected with buildings or housing. Only Turban (1967) classifies the term plant maintenance referring also to the building maintenance. Because of the unsatisfactory defined
terminology there are in use conflicting ideas even in the basic topics of apartment building maintenance.

The apartment building maintenance was defined in the introduction of this paper. British Standard (1974) BS 3811:1974 defines terms used in the general maintenance aspects of terotechnology. It is concerned with all physical assets such as buildings, plant, machinery, equipment, and structures. The apartment building maintenance belongs to the definition of terotechnology: a combination of management, financial, engineering and other practices applied to physical assets in pursuit of economic life cycle.

The British Standard definition for maintenance is:
"Maintenance is a combination of any actions carried out to retain an item in, or restore it to, an acceptable condition".

The standard gives 47 definitions that are connected to the general terms used in maintenance organization. There are mentioned some terms which should not be used in the connection of maintenance. However, some terms are quite usual in the maintenance literature.

The British Standard definition of maintenance and its subterms is naturally authoritative. There are, however, also some other studies dealing with maintenance terms and definitions. Priel (1974) defines maintenance referring to all the activities which assist in keeping plant and equipment in good condition. The definition of Lewis (1963) is different than in British Standards. He has 27 definitions that are peculiar to maintenance management and to maintenance control. Goldman and Slattery (1964) have glossary of terms in maintainability with close connection to maintenance. Their definition to maintenance in general is similar to that of British Standard. Blanchard and Lowery (1969) have defined the maintenance engineering as "an organization or function that is usually
associated with the tasks of maintenance analysis, maintenance studies, maintenance-policy generation, support planning, and maintenance-procedures development".

With references to several papers, the concept of apartment building maintenance can be said to include the following components (Priel, 1974; Lewis and Marron, 1973; Blanchard and Lowery, 1969; British Standards, 1974; Lawson, 1976):

1. Repair and operating maintenance
   a. Emergency maintenance
   b. Breakdown maintenance
   c. Running maintenance
   d. Planned maintenance
   e. Preventive (corrective) maintenance
   f. Shut-down maintenance
   g. Major repairs
   h. Alterations and improvement

2. Housekeeping maintenance
   a. Janitorial services
   b. Maintenance of grounds
   c. Operating services

These components can be found both in industrial plant maintenance and in building maintenance. Compared with industrial maintenance the apartment building maintenance is concentrated more to the housekeeping maintenance.

These components can be found both in industrial plant maintenance and in building maintenance. Compared with industrial maintenance the apartment building maintenance is concentrated more to the housekeeping maintenance.

3. INDUSTRIAL MAINTENANCE AS A BASIS OF BUILDING MAINTENANCE STUDY

It has been more profitable in industry from 1850's to 1960's to concentrate on increasing production than to improve the efficiency of maintenance (Lewis, 1963). In housing the massive production of new homes has overshadowed the attempts to rationalize the building maintenance.
The principle of the apartment building maintenance is identical or close to the industrial plant maintenance system. Some special characteristics, however, vary between building and plant maintenance. Lewis and Marron (1973) define the activities of a maintenance engineering department. They are different in each plant and influenced by plant size, company policy, and industry. The organizations in the industrial plant maintenance are larger and more specialized than in an average apartment building maintenance organization. In Fig. 2.1 there is shown the organizational and hierarchical difference between industrial and building maintenance personnel structure.

The number of maintenance hourly employees per supervisor, N, in 500 industrial firms in USA in 1969 was $8 \leq N \leq 13$, the average ratio was $11:1$ (Lewis and Marron, 1973). There is slight variation in the ratio among the various industries, but no significant variation in the ratio among industrial groups based on type of manufacture. The report notes that in production departments, an hourly to supervisory ratio 20:1 or greater is not uncommon. This is attributed to the extensive staff support provided to production supervisors.

In the small and medium sized apartment maintenance organizations the superintendent has the supervisory role of an industrial plant maintenance organization. The ratio maintenance laborers per supervisor, N, in a maintenance group with 1000...2000 apartments is $9 \leq N \leq 15$. In these Finnish organizations all maintenance laborers are included, including cleaners. In smaller organizations the ratio is lower. In maintenance groups with 400...700 apartments the ratio is $6 \leq N \leq 9$, and in very small units is no special supervisor at all. The ratio based on salary comparisons of part-time supervisors and maintenance laborers is $2 \leq N \leq 5$.

The ratio, N, in apartment maintenance tends to inform that the maintenance personnel has much more supervision in smaller maintenance groups. However, the supervision
is not directed to the personnel. Often the personnel in small maintenance groups, especially when traditional method utilized, may work independently and almost without any supervision. As the size of maintenance group grows the supervision of maintenance tends to be more effective although the value of ratio $N$ increases.

Newbrough (1967) has studied the industrial maintenance and repair costs as a percent of plant and equipment. This percent, $p$, in USA in 1967 was $2.6 \% \leq p \leq 12.8 \%$, median was $p = 6.3 \%$. The maintenance and repair costs are highest in automotive and steel industry, lowest in petroleum and radio-television industry.

The technical apartment building maintenance costs (heating, repair, labor, garbage disposal and administrative costs) as a percent of buildings and equipment, $p$, are in Finland in 1977 $2.7 \% \leq p \leq 3.8 \%$. The direct maintenance costs (repair, labor, and administration) are $1.4 \% \leq p \leq 2.8 \%$. The value of buildings and equipment is evaluated with the initial costs of government subsidized apartment buildings in 1977. The maintenance costs of apartment buildings are lower than those in industrial plant maintenance which is more complicated from the technical point of view and which demands more labor force. The reason in the variation of ratio $p$ is the age of apartment building and possession aspects (tenement building vs. apartment-owning company).

There are some other indices and indicators to measure the width and complexity of maintenance in an industrial plant or other system. Newbrough (1967) gives an estimate for industry in general that the expenditures for maintenance and repair averages 5% of the sales dollar, in steel industry as high as 12%. In apartment buildings the technical maintenance costs are 45...70% of all annual expenditures. Hence, the maintenance costs are much more dominant in apartment building maintenance than in industrial plant maintenance.
Figure 2.1

The personnel organization differences between industrial plant maintenance and apartment building maintenance.

There are several papers dealing with the cost and system effectiveness from the maintenance point of view (Goldman and Slattery, 1964; Blanshard and Lovejoy, 1969). However, the books deal more with the maintainability aspects.
MAINTENANCE PLANNING, ORGANIZATION AND SYSTEM EFFECTIVENESS

There are some fundamental studies dealing with the organizational aspects of maintenance (Lewis, 1963; Corder, 1974). Priel (1974) has studied the effect of introducing planned maintenance on the total workload of a ten-man team. In an ideal system the total maintenance workload decreases 25% due to preventive effects of planned workload. The basic reason for this effect is the improved use of working time. He has also defined the maintenance performance ratios.

Kelly (1972) reports that when organizing proper maintenance control a procedure which includes pre-determined work delegation and plant feedback information is essential. Copper has studied the role of building and plant maintenance in works engineering department. He gives the required features of a preventive maintenance system, and the requirements for definite work control (Copper, 1963).

Lewis and Marron (1973) state that in three surveys (Franck, 1962; Booz-Allen, 1965; Turban, 1865) in USA the lack of preventive maintenance has been reported to be a serious problem of industrial maintenance. The surveys show general agreement on major problem areas in maintenance. Frank (1964) has also a survey of maintenance inefficiency. The reason for maintenance inefficiency in 157 industrial companies was management neglect. 58% of the companies stated that they have no objective and realistic measure of the hourly maintenance employees. The most serious problems in maintenance were:

a. Work measurement
b. Planning and scheduling
c. Lack of preventive maintenance.

There are several papers dealing with the cost and system effectiveness form the maintenance point of view (Goldman and Slattery, 1964; Blanchard and Lowery, 1969). However, the books deal more with the maintainability aspects.
4.1 Maintenance organizations

There are some fundamental studies dealing with the organizational aspects of maintenance (Lewis, 1963; Corder, 1968; Newbrough, 1967; Priel, 1974; Clementes and Par- kes, 1963). Priel has studied the size of maintenance organizations in industrial plants. He classifies the maintenance organizations in the following three groups:

a. Maintenance team
   - maintenance workforce 8-25 persons
   - personnel is divided in professional areas

b. Maintenance section
   - maintenance workforce 20-50 persons
   - maintenance personnel is divided in stores, planning and control, repair crews, and fixed maintenance assignments

c. Maintenance department
   - maintenance workforce 50-200 persons
   - maintenance department is usually divided in three branches: mechanical, electrical and building branch
   - each branch has its subdivisions.

4.2 Operations Research in Building Maintenance

In the literature devoted to the possibilities of operations research in the main-
tenance of apartment buildings, there is little emphasis on the role of optimization in the general problem of operations research models in implementa-
tion. The optimization of apartment maintenance organization is one of the most fundamental problems of the overall development in apartment maintenance.

In industrial plant maintenance the problem of maintenance centralization versus decentralization has been studied in many papers. The problem has same characteristics as in apartment building maintenance. Both centralization and decentralization have their advantages. Decentraliza-
tion is suitable especially for minor repairs (Lewis and Marron, 1973). In general, decentralization of maintenance is a solution which should be only selectively applied (Priel, 1974). In industrial maintenance with the same features as apartment building maintenance the arrangement of an area maintenance system has the following advantages:

1. Closer contact between maintenance organization and production or operations (apartments, tenants, housing process).

2. Geographical specialization reduces unnecessary transportation time and some work incrementals.

The area-maintenance systems are increasing in the apartment building maintenance.

4.2 Operations Research and Systems Study in the Apartment Building Maintenance

In the literature very little attention has been devoted to the possibilities of operations research in the maintenance studies (Turban, 1967). However, in the last years some interesting studies have been conducted (Jardine, 1970). Especially the interrelationship between maintenance and decisionmaking has received more attention.

Turban describes and discusses the results of a national survey on the use of mathematical models in plant maintenance decision making (Turban, 1967). The determinants of the models are similar to those involved in the general problem of operations research models in implementation, despite the technological character of maintenance decisions. Turban states that in plant maintenance management the gap between theory and practice is very wide. Major restraints on use of maintenance mathematical models by Turban after several references are:
a. Low priority of maintenance
b. Lack of historical data
c. Lack of common language between maintenance, production and management.

In the Manual of Maintenance Engineering there is a review about the possibilities of OR in maintenance (Clements and Parks, 1963). It has been stated that simulation is very effective in maintenance study since maintenance is a system for which a generalized mathematical solution is usually not available. Also, it is difficult to establish the average behavior of maintenance system for pure mathematical maintenance models.

The Game theory has also been applied in maintenance (Campell, Pierce, and Torgersen, 1964). In the maintenance game the maintenance system is divided into two discrete models for handling mutually exclusive events: the maintenance system operating in steady state, and the maintenance system in a transient condition. The principle of the maintenance game could be applied in the apartment building maintenance.

Lifsey (1965) has demonstrated that dynamic programming can be used to optimize management decision required for the equipment maintenance function. The study shows that the method can be applied to large-scale systems of maintenance.

The arrangement of traditional building maintenance has been established in 1960 with Government Committee paper (Kotitekniiktintt, 1969). The monthly wages of maintenance survey over apartment building maintenance in various countries

The point principle has been introduced by using the syntactical contract estimation method. The tasks of maintenance methods in various countries has been collected during the study trips by author in Sweden, Finland, Canada, USA, Poland, Czechoslovakia, and West Germany in 1974, 1975
and 1976; and partially, under guidance by author, through the Industrial Attaches of Finland in Japan, England, Netherlands, West Germany, and USA.

The review in this study has been limited to the aspects closely related to the building maintenance in Finland. A special attention has been given to the productivity study of building maintenance.

5.1 Finland

Based on the official statistics 1) there are some 840 000 buildings in Finland in 1970 totalling 611 million BM3, Tableau 2.1. Buildings for housing compose the major part of all buildings, counted both with volume and by number. Approximately 47 100 persons are working in the building maintenance, when one-family-houses are excluded; 41,4 % of these people are working in apartment building companies, Tableau 2.2.

In years 1948 to 1970 the increase of labor costs in apartment maintenance has been much faster than the increase of heating costs, Fig. 2.2. Actually, the price of heating oil, and especially its real value if inflation is taken into account, has declined in 1960's. In the period 1970 to 1975 the price of oil has increased.

The arrangement of traditional building maintenance has been established in 1969 with Government Committee paper (Komiteanmietintö, 1969). The monthly wages of maintenance men are based on a special point counting principle.

The point principle has been introduced by using the synthetic contract estimation method. The tasks of maintenance men are in constant relation to each other.

Task entireties are formed. In each building company the points are counted after two main categories:

a. Base time; depending mainly on the size of the building company.

b. Incremental times; are caused by the characteristics of buildings.

The points are counted mostly from the following:

- Heating works
- Outside cleaning
- Repair works of running and general nature: fixings, small repairs, etc.
- Overall control and garbage disposal.

The number of work points for each building company are estimated only once, supposing there is no technical change in the properties.

The maintenance cooperation between apartment-owning companies and maintenance methods.

The points have a certain value, the level of which bargained annually by labor and trade unions, Fig. 2.3.

In 1971 and after that the minimum salary (concerns also maintenance personnel), 40-hour and 5-day work weeks have been introduced; for this reason personnel for week-end and night duties are required in the building companies. Technical development of maintenance machines and remote control installation has been improved considerably. Also the average maintenance load of separate building companies has increased especially in the new homogeneous building areas. The continuous increasing use of district heating has changed essentially the nature of apartment maintenance work by the elimination of heating work in buildings.

In 1970's the large building companies utilizing service men system has been introduced for building maintenance work. The service men are doing any kind of maintenance work for constant monthly salary; 40-hour and 5-day-week is used. Very often the service men are specialized in two major areas of maintenance: repair works and outside cleaning.
There are, salarywise, two types of servicemen: usual servicemen and plant servicemen having 2% higher salary. The actual difference in works is small. For evening and weekend duties the compensation is similar to that for traditional maintenance men.

In Fig. 2.4 there is shown, as an example, an organization. Before 1960 the apartment building companies in Finland have been relatively small, including one or two buildings with 20 to 50 apartments. The main reason lays in the Law of Apartment Owning Companies from the year 1926. By this Finnish law each building with its land area constitutes a legal real estate stock company owned by the apartment-owners in the building. The apartments are owned by stocks.

The maintenance co-operation between apartment-owning companies has been minimal in 1926 to 1960. Separate companies have been operating independently utilizing traditional maintenance methods.

The model of centralized building maintenance has been introduced in Finland in 1960's, the idea imported from Sweden. Then in 1960's large homogeneous areas of blocks of flats were built in Finland. Particularly municipal tenement buildings were built in uniform areas. At the same time the area and district heating systems started to become more common. The building companies which first introduced servicemen system claim that the centralization of heating has been the basic reason for the utilization of specialized servicemen system.

In 1970's the large building companies utilizing servicemen system have been common also among the apartment owning companies: the separate, still legally independent companies, have made an agreement about founding a service firm for some building area. The operations of this firm limit only for this building area. In regulations issued by the Government of Housing in 1973 and 1974, the independent apartment building companies are obliged to.
form a common maintenance service company for a certain uniform building area and to utilize its services. Usually this is controlled by strict orders in the land leases from the city.

In Fig. 2.4 there is shown, as an example, an organization chart of a large apartment building company in Finland utilizing servicemen maintenance. The operations in a uniform area are divided in three subareas each having a supervisor, foreman and six servicemen. The approach is the same in smaller building companies: usually there are no subareas. The servicemen under a supervisor are usually divided into two crews: repair crew and machinemen for outside cleaning.

In Tableau 2.3 there is shown the breakdown of maintenance personnel in seven apartment and tenament building companies in Finland in 1977. As a comparison is shown the personnel of a student residence, hospital and industrial office building.

In Finland there are no national or local organization for the apartment or other building companies. This is a very fundamental difference compared for instance with Sweden. Therefore there is no long-range planning, research or development over the building maintenance organized by building companies; the separate building companies, however large, are economically unfeasible for reasonable maintenance development or study. Thus, the study in the building maintenance area is going to be done by state authorities, financed and directed by the Government of Housing.

The big cities in Finland have large number of apartment under their direct or indirect control, for instance in Helsinki over 20,000 apartments. The Finnish approach, however, is or is going to be that these municipal tenaments will be given to one special company which is owned by area building companies in the locality. Thus, the control by the city is rather formal and the building companies can manage themselves independently.
### ALL BUILDINGS

<table>
<thead>
<tr>
<th>Type of Buildings</th>
<th>Number of buildings</th>
<th>Volume of buildings 1000 BM3</th>
<th>Average Volume BM3/building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row-houses</td>
<td>9 419</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apartment buildings and houses</td>
<td>768 204</td>
<td>366 004</td>
<td>59,9 %</td>
</tr>
<tr>
<td>Industrial buildings</td>
<td>22 020</td>
<td>117 223</td>
<td>19,2 %</td>
</tr>
<tr>
<td>Office and commercial buildings</td>
<td>21 464</td>
<td>44 683</td>
<td>7,3 %</td>
</tr>
<tr>
<td>Hospitals and other institutions</td>
<td>3 148</td>
<td>15 482</td>
<td>2,5 %</td>
</tr>
<tr>
<td>Public buildings</td>
<td>19 263</td>
<td>69 998</td>
<td>10,8 %</td>
</tr>
<tr>
<td>Other buildings</td>
<td>3 849</td>
<td>1 612</td>
<td>0,3 %</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>837 948</td>
<td>611 021</td>
<td>100 %</td>
</tr>
</tbody>
</table>

### BUILDINGS FOR HOUSING

<table>
<thead>
<tr>
<th>Type of Buildings</th>
<th>Number of buildings</th>
<th>Volume of buildings 100 BM3</th>
<th>Average Volume BM3/building</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-family houses</td>
<td>713 992</td>
<td>196 882</td>
<td>53,8 %</td>
</tr>
<tr>
<td>Row-houses</td>
<td>5 201</td>
<td>9 419</td>
<td>2,6 %</td>
</tr>
<tr>
<td>Apartment buildings</td>
<td>49 011</td>
<td>159 703</td>
<td>43,6 %</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>769 204</td>
<td>366 004</td>
<td>100 %</td>
</tr>
</tbody>
</table>

Tableau 2.1
Number and volume of buildings in Finland in 1970.
(Office of Statistics in Finland, 1974).
<table>
<thead>
<tr>
<th>Volume 1000 BM3</th>
<th>1) Annual use manhour/BM3</th>
<th>2) Manyyears/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row-houses</td>
<td>9,419</td>
<td>0,08</td>
</tr>
<tr>
<td>Apartment buildings</td>
<td>159,703</td>
<td>0,22</td>
</tr>
<tr>
<td>Industrial buildings</td>
<td>92,020</td>
<td>0,15</td>
</tr>
<tr>
<td>Commercial buildings</td>
<td>21,464</td>
<td>0,25</td>
</tr>
<tr>
<td>Hospitals, etc.</td>
<td>3,148</td>
<td>0,45</td>
</tr>
<tr>
<td>Public buildings</td>
<td>19,263</td>
<td>0,20</td>
</tr>
<tr>
<td>TOTAL</td>
<td>305,017</td>
<td></td>
</tr>
</tbody>
</table>

1) Estimate by author based on field survey.
2) One manyyear is supposed to have 1,800 manhours.

Tableau 2.2
An estimate of the use of personnel in building maintenance. All maintenance workers included.

Tableau 2.3
Building maintenance personnel and use of manpower/m^3 in seven typical apartment and tenement building companies in Finland in 1977. As a comparison a student residence, large hospital and industrial building. One building maintenance personnel in manyear has 1,800 manhours.
<table>
<thead>
<tr>
<th></th>
<th>2)</th>
<th>1)</th>
<th>1) 1)</th>
<th>1) 2)</th>
<th>1000</th>
<th>Hospital</th>
<th>Industrial and office buildings 1.142</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management personnel and foremen</td>
<td>0,2</td>
<td>0,5</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Administration and tenant service</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Servicemen and janitors</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>11</td>
<td>9</td>
<td>21</td>
<td>7</td>
</tr>
<tr>
<td>Cleaners for inside cleaning</td>
<td>-</td>
<td>1</td>
<td>6</td>
<td>9</td>
<td>16</td>
<td>17</td>
<td>32</td>
</tr>
<tr>
<td><strong>TOTAL (persons)</strong></td>
<td>1,2</td>
<td>2,5</td>
<td>15</td>
<td>26</td>
<td>32</td>
<td>45</td>
<td>76</td>
</tr>
<tr>
<td>Use of manpower, man-hours/m³/year</td>
<td>0,31</td>
<td>0,23</td>
<td>0,21</td>
<td>0,18</td>
<td>0,16</td>
<td>0,14</td>
<td>0,36</td>
</tr>
</tbody>
</table>

1) Tenament companies, 2) One or several small own heating centers in the company.

Tableau 2.3
Building maintenance personnel and use of manpower/m³ in seven typical apartment and tenament building companies in Finland in 1977. As a comparison a student residence, large hospital and industrial building. One building maintenance personnel in manyear has 1 800 manhours.
Figure 2.2
Index for all labor costs and heating oil in Finland in 1948...1975. Five year periods. The costs in 1948 = 100. The hourly salary for male industrial workers in Finland in 1975 was 13.39 Fmk/hour, and the customer price of heavy heating oil was 0.34 Fmk/kg (Ref: Office of Statistics, Finland, and the statistics of Neste-oil company, Finland).
Figure 2.3
The value of work points for maintenance men in traditional building maintenance in Finland. Based on labor and trade contracts.
In England there are several large maintenance branch organizations own and run large and small buildings. In Finland a system has reorganized its maintenance branch of the Ministry of Housing and Construction 1966-1976. The system has been introduced in eight cities in USA, with costs of a US$ 2 millions of dollars. London is much larger and more centralized.

Figure 2.4
Organization chart of a large (3 700 apartments) apartment building company in Finland using centralized serviceman system. The building (service) company is composed of several independent apartment-owning stock companies. Company uses district heating.

In 1967 Management Consultants were employed in order to reorganize the maintenance operations. Work study techniques and improved working methods were introduced. In 1975 by a reorganization the then 8 district organizations were divided into 18 districts under a control unit (Fig. 2.6). Each district is responsible for about 13 000 properties and has the following offices with their typical number of laborers:
5.2 England

In England the municipal housing organizations own and run large numbers of dwellings. The building maintenance branch of the Greater London Council of Housing has reorganized its maintenance methods during the period 1966-1976. The system has been adopted by other authorities in Britain and France, and in 1977 it has been introduced in eight cities in USA, with the backing of a US$ 2 millions of Federal Research Grant.

It has also been taken up by a new international body for exchanging research information on local government technology and policy, the International Urban Technology Exchange Programme (IUTEP). The member countries are: USA, France, West Germany, and United Kingdom.

The system is widely applicable also to building maintenance in Finland, especially in big cities among the municipal tenament building companies centralized in uniform areas. Compared with the municipal housing and building maintenance organizations in Finland, the organization in London is much larger and more centralized.

The Greater London Council of Housing (Fig. 2.5) maintains 205 000 dwellings comprising some 126 000 flats, 70 000 cottages and 9 000 miscellaneous properties. The maintenance branch has over 4 000 laborers, 1 000 vehicles for transportation, annual budget totals £ 40 (290 million Fmk/year).

In 1967 Management Consultants were employed in order to reorganize the maintenance operations. Work study techniques and improved working methods were introduced. In 1975 by a reorganization the then 8 district organizations were divided into 18 districts under a control unit (Fig. 2.5). Each district is responsible for about 13 000 properties and has the following offices with their typical number of laborers:
- Works manager (1 person)
- Works office (5 persons)
- Technical surveys (3"
- Productivity and cost control (3"
- Building trades (88"
- Painting (109"
- Transportation (8"
- Site security (2"
- Gardening (20"

Each district has its own central depot and those with a wide geographical spread have sub-depots at peripheral estates. In each district depot there is a planning center which monitors the progress of each job (job tickets).

In the Maintenance Branch approximately 750,000 job tickets are completed annually in addition to painting 40,000 dwellings. 90% of works have been done by own staff. 10% are done by subcontractors: glazing repairs, asphalt works, metalwork repairs, etc. and normal trade jobs during peak work loads. 13% of jobs are emergency works, most completed with 24 hours of origin.

Team organization approach has been introduced. Each depot has a team for each of the main building track groups. Within each team:

(i) some tradesman operate individually in minivans dealing with emergency or urgent works
(ii) other tradesman are formed as a mobile team visiting areas of their district in turn of about 7 working day intervals
(iii) the chargehand drives a team vehicle which is equipped with material, parts and equipment.

Thus the maintenance service is loaded by maintenance work. The maintenance branch has increased the level of service both in respect of repairs and preventive maintenance. The maintenance branch claims that the level of service both in respect of repairs and preventive maintenance is increased by the team approach.

Teams are being specially trained at intervals in the departments training workshops.
The 1,700 painters of Maintenance Branch are organized within districts into small gangs of approximately from 10 to 12 men supervised by chargehand. Painting superintendents control approximately 7 gangs.

There has been a considerable increase in the productivity of maintenance during the period 1965-1976 (Graham, 1977). The output of effective performance \((\text{Eq. 2.1})\) has increased 104%:

\[
E_p = \frac{P_s}{G_h} \times 100
\]

\[(2.1)\]

where

- \(E_p\) = effective performance
- \(P_s\) = productive standard hours
- \(G_h\) = gross hours worked

The productive standard hours corresponds to the total work load of maintenance.

The effective performance \(E_p\) measured per labor has been as follows;

- In 1966:
  \[E_p = \frac{4,022,250 \text{ productive hours}}{6,250 \text{ laborers}} = 643 \text{ prod.hours/laborer}\]

- In 1976:
  \[E_p = \frac{5,058,420 \text{ productive hours}}{3,860 \text{ laborers}} = 1,310 \text{ prod.hours/laborer}\]

Thus, the productive standard hours (work load by maintenance service standards) has increased 26%. At the same time the labor force has increased 38% by 2,390 operatives. The Maintenance Branch claims that the level of service both in respect of repairs and preventive maintenance programmes has been increased.
A computer job ticket analysis measures the weekly performance achieved. The introduction of work study techniques has produced a net financial benefit to the council of over £3.5 millions per year (24.5 million Fmk/year). A additional saving of over £1.27 million per year (8.89 million Fmk/year) has resulted from the introduction of the management of objectives discipline. The total benefit £4.77 million per year (33.39 million Fmk/year) equals the same as the saving of 23.27 £/dwelling/year (162.88 Fmk/dwelling/year).
Figure 2.5
Central organization of Maintenance Branch to the Greater London Council of Housing. The central organization totals about 226 employees and the 18 districts have 3,860 laborers.
Like in Finland, both the traditional maintenance method and the specialized service man system are utilized in building maintenance. District heating of buildings are run by city or municipal firm. There are also area heating systems and smaller heating units in separate buildings. The small heating units in buildings, however, are going to be renovated and modernized either by gas or by electrical heating.

In West Germany the inside cleaning of stair cases and other building areas is very often done by the tenants in turns. The cleaning duties of tenants are given with punctual regulations. This approach is very uncommon in other countries and not used in Finland. Especially in small buildings the system is very practical.

In large apartment building companies 1) the technical maintenance operations and tenant service are usually divided in districts each having about 1,500 apartments. The companies may have from 5 to 15 maintenance districts.

Districts have usually an engineer, an assistant engineer, office employee for tenant service and service men. The service men take care of outside cleaning by machines and of running repair works. The major part of repair and similar repair works, however, is often let to be done by subcontractors; in a higher degree than in Finland. In some cases all repair works are done by subcontractors.

1) Reference with the two organizations studied in detail: Deutsche Wohnungsgesellschaft mbH (DEWOG), Cologne, West Germany; and Gemeinnützige Aktiengesellschaft für Wohnungsbau, Cologne, West Germany.
All administrative and financial works are done in the central unit common to all districts: rent control, bookkeeping, material works.

The traditional maintenance method is in a high degree similar with the system used in Finland. The repair works, however, are more often than in Finland done by subcontractors or other outside firms. The salaries of maintenance men (janitors) are based on the number of apartments and the area of outside areas. In big buildings the full-time basis of work is used, in smaller building the part-time basis. Then, very often, the system is that the janitor (husband) is taking care of outside areas and his wife takes care of inside cleaning while most of the repair works are done by outside firms.

In each district the heavy maintenance machines for repair works in outside areas and all administrative works have been concentrated in a central station. The

Sweden

The apartment building maintenance in Sweden is in a high degree centralized. The number of dwellings for housing totals 3,4 millions, 60 % of which are apartments. Most of these apartments are run by two housing organizations (SABO and HSB) operating nationwide:

- SABO: 640 000 apartments 32 % \( \frac{1,12}{4} \) million
- HSB : 480 000 apartments 24 % apt, 56 % of
- Others: 880 000 apartments 44 % all apt.

Total: 2 000 000 apartments 100 %

Some 75 % of all apartments are in tenement building companies and 25 % in apartment owning companies (dwellings owned by the tenants). The HSB-company is co-operative housing organization while SABO is an organization of general use.

The central administration of both HSB and SABO take care of the research and development in the building maintenance area; the costs are charged from apartments. Tech-
technical maintenance personnel and district organizations are provided with maintenance manuals and supported with operative instructions from the central administration. General rules for building management are followed in each district company.

The two organizations are divided in district so that in each big or medium sized city there is a district organization. In a district there may be up to 38,000 apartments (like AB Göteborgshem, Gothenburg, Sweden). The districts (Fig. 2.6) are usually divided into area offices. The area offices are regarded small if there are less than 1,500 apartments, medium sized with 2,000 to 5,000 apartments, and large if it totals more than 5,000 apartments.

In each district the heavy maintenance machines for repairs and works in outside areas and all administrative works have been concentrated in a central station. The area office takes care of tenant service and all running maintenance works, Fig. 2.6.

Very small building companies in small towns are operating directly under the administrative office of national organization. These companies run their technical maintenance, however, rather independently.

In district and area organizations the specialized serviceman system is utilized. Only in small building companies the traditional maintenance is sometimes used. Most of the repair works are done by own personnel.

The remote control of buildings and advanced building automation are often utilized especially in large building companies.

In the last years, especially in 1976 and 1977, there has been a serious concern about the housing-comfort particularly in very large apartment building areas. There
exists a strong demand to decentralize considerably the tenant service and service man system of highly concentrated district organizations. The problems in the housing-comfort area tend to overshadow the problems of technical building maintenance.

The service man model of centralized building maintenance has been introduced from Sweden to Finland in the 1960's. The Finnish system of centralized building maintenance has characteristics of small district or medium sized area offices in Sweden. The large apartment building companies tend to follow the development of building maintenance in Sweden, much more than in other countries.

Figure 2.6
Organization chart of two district maintenance organizations in Sweden (HSB). The district offices are controlled by the national central administration.
Figure 2.6
Organization chart of two district maintenance organizations in Sweden (HSB). The district offices are controlled by the national central administration.
Japan

The considerable production of apartment buildings started in Japan after 1945, along with the state subsidized home production. There are three dominant housing organizations on Japan:

1. Japan Housing Corporation
2. Japan High-rise Apartment Association
3. Tokyo Metropolitan Office of Housing Bureau, Management and Maintenance Department

For example, the Japan Housing Corporation runs about 500,000 apartments in tenement buildings, Fig. 1. The organization is divided in three levels:

(a) Head quarter office in Tokyo
(b) 5 District offices around Japan
(c) 25 Maintenance area offices

In each maintenance area, Fig. 2.7, the building companies use to establish subsidiary companies for maintenance service firms. They take care of administration, repair works, general service, inside cleaning, rent collection and control, tenant service, etc. This is so called total maintenance approach which is becoming the system most used. A former approach was so called operative maintenance arrangement; only administrative and financial works were done in the maintenance area office, while all other maintenance and service works were given to the outside subcontractors.

In Japan the Ministry of Building and Housing is doing research work about the management and maintenance of apartment buildings, mainly including statistical studies.
In the development of maintenance systems and in the operation of maintenance operations it is necessary to take the following into account:  

1. Co-operative use of heavy or advanced maintenance machinery (tractors, trucks, remote control installation) and specialized maintenance personnel between maintenance groups; optimal use of maintenance resources.
2. Standardization of maintenance methods and use of common service firms in the maintenance area.
3. Development of district service stations and control centers for building maintenance.
4. Optimizing the size of maintenance area in response to the maintenance load and resources.
5. District office Maintenance Department.
6. Maintenance manuals for operative personnel and instructions for tenants.
7. Automation and mechanization of routine operations.

Figure 2.7
Organization chart of Japan Housing Corporation. 500,000 apartments in tenement buildings.

(a) Central offices
1. Headquarters in Tokyo - general administration
2. District
3. District office Maintenance Department
4. District
5. District
6. Area Offices
   - 4 to 6 Maintenance Area Offices per District
   - 20 to 40 persons/office
   - 20,000 to 30,000 apartments/office
7. Area Offices
   - Inside cleaning staff.
8. Area Offices
   - In outside cleaning staff.

(c) City or Town (Area of Potential Urban Operations)
1. Development of large apartment maintenance systems; long distance heating, warning control center, etc.
III: BACKGROUND FOR THE FIELD STUDY IN FINLAND

1. PROBLEM AREAS OF BUILDING MAINTENANCE IN FINLAND

   a. Maintenance Group

      1. Centralization of heating systems to district or area heating systems.
      2. Rearrangement of the servicemen's work.
      3. Standardization of works and systematic operation of maintenance services, especially in repair work.
      4. Increase of mechanization degree, especially in outside cleaning work.
      5. Maintenance manuals for operative personnel and instructions for tenants to change the existing system.
      6. Automation and mechanization of routine and machine maintenance control.
      7. Optimizing the size of maintenance groups.

   b. Maintenance Area

      1. Co-operative use of heavy or advanced machinery (tractors, trucks, remote control installation) and specialized maintenance personnel between maintenance groups; optimal use of maintenance resources.
      2. Standardization of maintenance methods and use of common service firms in the maintenance area.

   c. City or Town (Area of Potential Urban Operations)

      1. Development of large apartment maintenance systems: long distance heating, warning control centers, etc.
2. Optimization of the use of various maintenance service firms.
3. Strategic maintenance plan for the city.

(d) State, Province, Country
1. Long-range (5-15 years) plan for the overall development of apartment maintenance: Centralization of maintenance, use of large heating systems, etc.
2. Consulting in the administrative and managerial area of apartment maintenance.

In practice, the model of apartment maintenance includes one or several submodels which studies one or several maintenance areas. The planning and development of apartment building maintenance can be simplified as indicated in Fig. 3.1. The importance of strategic and specially long-range plans are essential in local and nationwide development, and also in the short term maintenance planning of separate maintenance groups.

In many long term cases it may be difficult to change the existing building maintenance systems. The work methods and machinery are much easier for dynamic development process but they are related to a relatively high degree with the more static maintenance facilities. For this reason normative (long-range) and strategic maintenance plans should be available in order to take into account the future development in apartment maintenance. Today these plans are virtually non-existens.

The problem domain of apartment maintenance connected with other urban activities can be made clearer and easier to handle by dividing the problem by means of submodels. Then we can give for maintenance systems the following models:

a. **Macromodel**, which simplifies the apartment maintenance systems in urban areas and on potential maintenance load areas.
b. **Micromodel**, which simplifies the apartment maintenance operations and systems in a maintenance group or smaller units.

In both types of models we have the following subdivisions:

c. **Majormodel**, which determines the essential character of the system being studied.

d. **Minormodel**, which studies one or several details of the system being studied.

In practice, the model of apartment maintenance includes types of each model.

---

**Figure 3.1**: Width of planning and the planning horizon in the apartment maintenance.
As a statistical background study for the field study in Finland, the paper by the author was used (Kettunen, 1975).

By using statistical multivariate methods a model for the functional size of buildings, \( Y \), has been developed (Eq. 3.1);

\[
Y = f(S, R, E, R)
\]

where

- \( Y \) = maintenance technique (dimensional maintenance planning)
- \( S \) = index per apartment (heating methods)
- \( R \) = index per apartment (heating methods)
- \( E \) = index per apartment (heating methods)
- \( R \) = index per apartment (heating methods)

The following company indicates the locality and immediate neighborhood of the buildings.

The components of functional size in Eq. 3.1 are as follows

- \( u = \) physical size = \( f(S, R, E, R) \)
- \( w = \) maintenance type = \( f(V, x, T) \)
- \( z = \) standard of maintenance = \( f(P, R, T) \)

where

- \( S = \) volume of buildings
- \( H = \) level of maintenance technique; dimensions are equipment index, service index, number of workers.

Figure 3.1

Width of planning and the planning horizon in the apartment maintenance.
and p = common factor for the maintenance size and distance
K = total annual costs of the maintenance group
T = total annual unit costs of the maintenance group
V = building year of the maintenance group and with the
cline as the age connected components: m³/m², m³/apartment and
crease.
flat ratio
J = with the age connected maintenance technique; equip-
ment and service indices, heating system, distance
from service firms
P = apartment density; flat ratio, m³/apartment, m³/m²
R = factors connected with flat ratio; workers/apartment,
number stories, distance factors.
The common factors in model (Eq. 3.1) explain about
75% of the functional size of maintenance groups, when
comparisons are made based on the specific values of
these factors:
- cleaning works
- garbage disposal
It is important to notice that factors connected with
components of physical size and maintenance technique
are dominant in the functional size.
Factors connected with standard are important for speci-
fic maintenance groups, e.g., resident buildings.
Kettunen and Raouf have defined the service (P) and equip-
ment (v) indices\textsuperscript{1}) of apartment building maintenance
(Raouf and Kettunen, 1976; Kettunen, 1975). The indices
give plenty of information on both the arrangement of
maintenance in individual blocks of flats and the general
level of maintenance services in each locality. Both v

\textsuperscript{1) Service and equipment indices, }0 \leq P \leq 500 \text{ and } 0 \leq v \leq 100 \text{ correspond to the standard of maintenance machines and}
to the use of subcontractors in the maintenance operations
in a building company. The values of } p \text{ and } v \text{ increase
when the standard of machines and the use of outside firms
increase.
and \( p \) generally decline as the size of the locality becomes smaller. In each locality \( v \) and \( p \) increase as the size of the maintenance group grows larger. Roughly estimated, the maintenance costs of a residential area decline as the values of equipment and service indices increase.

In cities the including areas of service firms and their frequency of maintenance load increase as the size of the locality grows (Kettunen, 1975).

The common major maintenance works done by outside service firms are:

- administrative works
- janitorial works
- repair works
- cleaning works
- garbage disposal
- heating service

There are numerous minor maintenance works done by outside companies like pest destroy, security control, etc. However, the major maintenance works by firms have the basic role in a large-scale maintenance development of a locality.

---

The functional size of apartment (in Helsinki) and residential buildings in Finland:
- Apartments: \( f(15.0; 3.2; 2.0) = 136 \) units
- Residences: \( f(14.6; 4.0; 2.3) = 485 \) units

In addition to the size of maintenance group's functional size. As an example when choosing between student residences and usual apartment building (Kettunen, 1975).
a) Principle of the functional size of maintenance group, 
Y = f(u, w, z). Three examples.

b) The functional size of apartment (in Helsinki) and residential buildings in Finland:
Y/apartments = f(15, 0; 5, 2; 2, 0) = 156 units
Y/residences = f(14, 6; 4, 0; 8, 3) = 485 units

Figure 3.2
The principle of maintenance group's functional size. As an example the difference between student residences and usual apartment building companies (Kettunen, 1975).
1. MODEL FORMULATION FOR THE PRODUCTIVITY COMPARISONS OF MAINTENANCE SYSTEMS

In Equation (4.1) there are the following subproductivities:

\[
P = \frac{O}{I}
\]

where

\[P = \text{productivity of apartment building maintenance}\]
\[O = \text{output of maintenance}\]
\[I = \text{input of maintenance}\]

Model (4.1) is general in the nature. For more specific studies the total productivity of building maintenance, \(P_T\), is as follows (Eq. 4.2):

\[
P_T = \frac{O}{L+C+R+Q}
\]

where

\[P_T = \text{total productivity}\]
\[O = \text{total output of maintenance}\]
\[L = \text{total input of labor work}\]
\[C = \text{total input of capital investments}\]
\[R = \text{total input of material}\]
\[Q = \text{total input of other services and costs (costs for subcontractors, etc.)}\]

By formulating Eq. 4.2 the subproductivities can be defined as follows:

\[
\frac{1}{P_T} = \frac{L + C + R + Q}{O}
\]

The changes in the price and value coefficients have a...
\[
\frac{1}{P_T} = \frac{1}{L} + \frac{1}{C} + \frac{1}{R} + \frac{1}{Q} \quad \ldots(4.4)
\]

In Equation (4.4) there are the following subproductivities:

1. Productivity of labor work \( = \frac{O}{L} \)
2. Productivity of capital investment \( = \frac{O}{C} \)
3. Productivity of material \( = \frac{O}{R} \)
4. Productivity of other services \( = \frac{O}{Q} \)

The subproductivities can be further divided, like in Eq. (4.5), in details and with the principle of Eq. (4.4) the productivities for the details can be defined.

\[
P_L = \frac{O}{L_1 + L_2} \quad \ldots(4.5)
\]

where

\[ P_L = \text{productivity of labor} \]
\[ L_1, L_2 = \text{various labor work inputs} \]

In productivity calculations quantities are usually under consideration while values (money) is as measuring unit. Then the total productivity of Eq. (4.2) for the planning horizon, \( t \), is defined with Eq. 4.6;

\[
P_T = \frac{O_t}{C + L'1 + R'r + Q'q} \quad \ldots(4.6)
\]

where

\[ O_t = \text{total maintenance output during the planning horizon} \ t \]
\[ c, l, r, q = \text{price or value coefficients} \]

The changes in the price and value coefficients have a strong effect in the interrelationships of subproductivities.
The output of building maintenance productivity (Eq. 4.2 and 4.6) will be measured as the total building volume (cubic metres, m³) which have to be maintained with the given inputs. The inputs will be measured with monetary value (Finnish marks, Fmk). The input value in 1976 will be calculated to an annual cost with interest rate \( i = 8\% \) and planning horizon \( N = 8 \) years.

The dimension of Eq. (4.6) and (4.4) are as follows:

\[
\begin{align*}
PT & \rightarrow \left( \frac{m^3}{Fmk} \right) \\
\frac{1}{PT} & \rightarrow \left( \frac{m^3}{Fmk} \right)^{-1}
\end{align*}
\]

Thus, the dimension of Eq. (4.4) shows that the conversion of productivity in Eq. (4.6) gives the unit costs of building maintenance.

For valuation of the productivity of building maintenance with the Eq. (4.6) six size groups of building companies will be studied in detail: 10,000 m³, 50,000 m³, 150,000 m³, 300,000 m³, 500,000 m³, and 1,000,000 m³.

In the measurement of input, \( I \), the following will be studied:

\[
I = C + L + R + Q \quad \ldots (4.7)
\]

When

\[
\begin{align*}
C &= C_h + C_s + C_m + C_v \quad \ldots (4.8) \\
L &= b \cdot w \cdot v \quad \ldots (4.9) \\
R &= R_s \quad \ldots (4.10) \\
Q &= Q_m + Q_s \quad \ldots (4.11)
\end{align*}
\]

where

\[ Q_{m} \quad \text{is annual costs for the repair and service firms} \]
The basic equation, Eq. (4.12), does not give the overall productivity of building maintenance. Costs of garbage and repair materials are included. These costs, however, do not have to be considered because the costs are practically the same in any kind and

\[ C = \text{capital investments} \]

\[ C_h = \text{capital costs of heating installations} \]

\[ C_s = \text{foundering costs of the maintenance service spaces and/or buildings} \]

\[ C_m = \text{capital costs of maintenance machines, equipment and tools} \]

\[ C_v = \text{foundering costs of remote control installation and building automation equipment} \]

\[ L = \text{labor costs} \]

\[ b = \text{use of total labor work (manhours/m}^3$/\text{year) in the maintenance of a specific building company} \]

\[ w = \text{unit cost of labor work, Fmk/hour} \]

\[ V = \text{volume of building company, m}^3 \]

\[ R = \text{material costs} \]

\[ R_e = \text{energy costs (heating oil or heat bought from district heating company)} \]

\[ Q = \text{annual costs for subcontractors or other firms} \]

\[ Q_m = \text{annual expenses of machine rents or the use of machine firms} \]

\[ Q_s = \text{annual costs for the repair and service firms} \]

Terms \( L, R_e, \) and \( Q_s \) can be defined using the financial reports of building companies. Terms \( C_h, C_s, C_m, C_v \) and \( Q_m \) have to be studied separately in each maintenance group because there is no relevant statistical data available in Finland. Terms \( b, \) and \( d \) will be defined by using the collected statistics of financial reports and with more detailed studies in separate building companies.

With the terms of Eq. (4.2) and Eq. (4.7) the total productivity of building maintenance, \( P \), for comparisons will be as follows, Eq. 4.12:

\[
P_T = \frac{0}{(C_h + C_s + C_v + C_m + R + (Q + Q_s) (A/P, i=9\%, N)} \quad ... (4.12)
\]

In Eq. (4.12) the input costs will be calculated as annual costs with interest rate \( i = 9\% \) and \( N = 8 \) years in the capital recovery factor.
The basic model of the study, Eq. (4.12), does not give the overall productivity of building maintenance. Costs of garbage disposal, electricity, insurances, water and repair materials are excluded. These costs, however, do not have a fundamental effect for the productivity comparisons because the costs are practically the same in any kind and size of building company and maintenance type. Labor and machines, the Eq. (4.13) would give more specified information than the use of Eq. (4.12). However, the model of Eq. (4.12) is more suitable than Eq. (4.13) for maintenance arrangements.

2. PRODUCTIVITY MODEL OF BUILDING MAINTENANCE OPERATIONS

Unlike the productivity of building maintenance given with the Eq. (4.2) and Eq. (4.12) the productivity of building maintenance operations, \( P_0 \), is as follows, Eq. (4.13) and Eq. (4.14);

\[
P_0 = U \cdot M \cdot F,
\]

\[
P_0 = \frac{T_t - T_d}{T_t} \cdot \frac{M_t}{M_a} \cdot \left( \frac{F_s}{F_a} \right)
\]

where

- \( P_0 \) = productivity of building maintenance operations
- \( U \) = utilization
- \( M \) = methods
- \( F \) = performance
- \( T_t \) = total time for a maintenance work
- \( T_d \) = down-time of a maintenance work
- \( M_t \) = for a particular maintenance task the time it would take using the best methods known
- \( M_a \) = for a particular maintenance task the time it would take using the actual method
- \( F_s \) = worker's performance by accepted norm
- \( F_a \) = worker's actual performance.
Utilization is largely a measure of organizational efficiency, including the flow of work, supply of materials, and availability of adequate machines and tools. Methods is a measure of the efficiency of task design. And performance is a measure of the worker's ability and effort.

Concerning particularly the productivity of maintenance labor and machines, the Eq. (4.13) would give more specified information than the use of Eq. (4.12). However, the model of Eq. (4.12) is more suitable than Eq. (4.13) to the extensive comparisons of various building maintenance arrangements.

At the present, there is no relevant information available about the building maintenance for the measurement of productivity with Eq. (4.13). After this research work there will follow an experimental study in Finland which will define the productivity of building maintenance by using the model of Eq. (4.13). It seems very probable that the potential productivity of building maintenance operations would be much better if all visible improvements were made, especially in small building companies applying traditional maintenance methods. The results of this study support the same idea.

The building design between various maintenance groups is very close to each other because of strict control. The 1041 companies correspond statistically to all apartment buildings in Finland; the buildings controlled by state authorities total 70 percent of all buildings.

The building companies in the Set A are under continuous control; they are obliged to send their financial reports every year to the Government of Housing.

Set B: 798 randomly selected apartment building companies from various cities and towns in Finland, Tableau 5.2. The statistical questionnaires to
V: DATA COLLECTION

1. METHOD OF DATA COLLECTION

1.1 Statistical sampling.

The statistical field study was carried out in Finland. The data in the study are composed of two sets:

- Set A: 1041 apartment building companies from 12 cities and towns in Finland, Tableau 5.1 and Fig. 5.2. Building design of these companies is controlled by state authorities (Government of Housing). The buildings have at least 3 stories without elevator, or 5, 7, 9 or sometimes 11 stories with elevators. The buildings have common saunas, storages and often laundries.

- Set B: 798 randomly selected apartment building companies from various cities and towns in Finland, Tableau 5.2. The statistical questionnaires to
the building companies are formed as a basis the model by Kettunen (1975). Data for the Set B is collected by the Center of Statistics in Finland (Tilastokeskus, Helsinki).

The financial reports were collected from the years 1974 and 1975. In the questionnaires technical data concerning buildings, laborers, machines, tools and equipment, and the use of energy and material, were collected.

The data collection and formulation of Set A and Set B was carried out as shown in Fig. 5.2.

1.2 Field studies in separate building companies and various cities

The arrangement of apartment buildings' district maintenance was studied in the following 9 cities: Helsinki, Tampere, Turku, Vaasa, Jyväskylä, Kouvol, Kajaani, Oulu, and Rovaniemi. The data was collected over the following things:

a. District or area heating
b. Remote control of buildings by leased telephone lines
c. District warning control centers of buildings
d. Availability of maintenance service firms or subcontractors for apartment building companies
e. Planning of large apartment building areas in the locality.

The study in these 9 cities was based on interviews with municipal authorities and the representatives (managers) of selected building companies; the companies belong to the Set A or Set B.
<table>
<thead>
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<th>number of maintenance groups</th>
<th>number of apartments</th>
<th>apartments company</th>
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<tr>
<td>apartment-owning building company</td>
<td>637</td>
<td>29 917</td>
<td>47</td>
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<tr>
<td>tenement-building company</td>
<td>404</td>
<td>30 234</td>
<td>75</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1 041</strong></td>
<td><strong>60 151</strong></td>
<td><strong>58</strong></td>
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</table>

### CITIES

<table>
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<tr>
<th>CITY</th>
<th>1) Number of companies</th>
<th>Number of buildings</th>
<th>Number of apartments</th>
<th>$m^3$</th>
<th>apartments company</th>
</tr>
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<td>Helsinki</td>
<td>A 84</td>
<td>T 117</td>
<td>177</td>
<td>6 406</td>
<td>1 694 951</td>
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<td>(501 000)</td>
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<tr>
<td>Tampere</td>
<td>A 58</td>
<td>T 41</td>
<td>104</td>
<td>3 677</td>
<td>971 118</td>
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<td>(166 000)</td>
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<tr>
<td>Turku</td>
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<td>T 19</td>
<td>161</td>
<td>5 295</td>
<td>420 692</td>
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<tr>
<td>(164 000)</td>
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<td></td>
</tr>
<tr>
<td>Lahti</td>
<td>A 38</td>
<td>T 35</td>
<td>64</td>
<td>1 956</td>
<td>514 416</td>
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<tr>
<td>(95 000)</td>
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<td>1 982</td>
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<td>(92 000)</td>
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</tr>
<tr>
<td>(80 000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kuopio</td>
<td>A 41</td>
<td>T 23</td>
<td>48</td>
<td>1 716</td>
<td>594 914</td>
</tr>
<tr>
<td>(72 000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jyväskylä</td>
<td>A 36</td>
<td>T 22</td>
<td>48</td>
<td>1 518</td>
<td>423 509</td>
</tr>
<tr>
<td>(62 000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vaasa</td>
<td>A 31</td>
<td>T 91</td>
<td>48</td>
<td>1 161</td>
<td>314 585</td>
</tr>
<tr>
<td>(54 000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lappeenranta</td>
<td>A 39</td>
<td>T 30</td>
<td>57</td>
<td>1 149</td>
<td>310 906</td>
</tr>
<tr>
<td>(54 000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rovaniemi</td>
<td>A 27</td>
<td>T 15</td>
<td>46</td>
<td>976</td>
<td>262 035</td>
</tr>
<tr>
<td>(29 000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kajaani</td>
<td>A 24</td>
<td>T 15</td>
<td>31</td>
<td>795</td>
<td>220 483</td>
</tr>
<tr>
<td>(21 000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) A = apartment-owning company, T = tenant-building company
2) Population of city
<table>
<thead>
<tr>
<th></th>
<th>Companies with long-distance heating</th>
<th>Companies with district heating</th>
<th>Companies with own heating system</th>
<th>Together</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Number of companies</td>
<td>223 (27.9 %)</td>
<td>47 (5.9 %)</td>
<td>528 (66.2 %)</td>
<td>798 (100 %)</td>
</tr>
<tr>
<td>2. Volume of buildings (1 000 m²)</td>
<td>2 793</td>
<td>544</td>
<td>4 076</td>
<td>7 413</td>
</tr>
<tr>
<td>3. Apartment area (1 000 m²)</td>
<td>596</td>
<td>127</td>
<td>919</td>
<td>1 642</td>
</tr>
<tr>
<td>4. Number of people</td>
<td>23 735</td>
<td>5 500</td>
<td>36 824</td>
<td>66 059</td>
</tr>
<tr>
<td>5. Energy consumption (Gcal)</td>
<td>164 518</td>
<td>29 282</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6. Water consumption (1 000 m³)</td>
<td>1 880</td>
<td>433</td>
<td>2 722</td>
<td>5 035</td>
</tr>
<tr>
<td>7. Energy consumption/volume (Gcal/m³)</td>
<td>0.0589</td>
<td>0.0539</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8. Water consumption (m³) per building volume</td>
<td>0.67</td>
<td>0.80</td>
<td>0.67</td>
<td>0.68</td>
</tr>
<tr>
<td>9. Apartment area/company (m²/company)</td>
<td>2 672</td>
<td>2 702</td>
<td>1 741</td>
<td>2 058</td>
</tr>
<tr>
<td>Value of building property 1) in 10⁶ FMK</td>
<td>929</td>
<td>165</td>
<td>1 364</td>
<td>2 459</td>
</tr>
<tr>
<td>Value/company (10⁶ FMK)</td>
<td>4.12</td>
<td>3.51</td>
<td>2.58</td>
<td>3.08</td>
</tr>
</tbody>
</table>

1) Based on fire insurance values in 1975.

Tableau 5.2
Number and characteristics of the apartment building companies in the Set B (Center of Statistics, Finland).
Cities (population):
1. Helsinki  (505 000)
2. Tampere  (166 000)
3. Turku     (164 000)
4. Lahti     (95 000)
5. Oulu      (92 000)
6. Pori      (80 000)
7. Kuopio    (72 000)
8. Jyväskylä (62 000)
9. Lappeenranta (54 000)
10. Vaasa    (54 000)
11. Rovaniemi (29 000)
12. Kajaani  (21 000)

Figure 5.1
The cities in the Set A (Government of Housing).
Sample
Population

Size of Location
I; \(5 \leq p \leq 25\)
II; \(25 \leq p \leq 70\)
III; \(70 \leq p \leq 100\)
IV; \(100 \leq p \leq 200\)
V; \(p = 500\)
p = 1,000 people

Size of Maintenance Group
I; \(s \leq 4\)
II; \(4 \leq s \leq 15\)
III; \(15 \leq s \leq 40\)
IV; \(40 \leq s\)
s = number of buildings in the maintenance group

Type of Maintenance System
I; traditional maintenance
II; specialized maintenance
III; apartment maintenance using subcontractors

Special Factors
a. Type of heating system
b. Age of the buildings
c. Geographical location of the city
d. Location of the department building company in the city or built-up area.

Figure 5.2
Data collection and set formulation in the field study, and the major objects of investigation.
Figure 5.3
City-areas in various sizes of localities.

Figure 5.4
Suburban area in Helsinki, Finland (Pasila-area). The maintenance area has a computerized building automation system and centralized maintenance organization.
VI. ANALYSIS

1. SURVEY OVER THE STATISTICAL RESULTS OF THE STUDY

Data, however, are higher in buildings with district heating than in buildings when own heating systems higher and tenant building companies are higher (Tableau 6.2). The heating costs include the costs of heating oil. In Tableau 6.1 there are shown the running costs of building companies in Set A in 1975. The emphasis of this study lays in the technical maintenance costs (Tableau 6.2) including the following subcosts:

- Labor costs
- Heating costs
- Inside cleaning
- Repair costs

Excluded are capital costs of buildings, water, electricity, insurance, and tax costs. They do not have a direct effect on the building maintenance operations. Excluded are also all heating work, as will shown later. The size of technical maintenance costs are higher in tenament buildings than in apartment owning companies (Tableau 6.2): 19.9% higher when own heating system is utilized and 19.5% higher when district heating system is utilized.

In general, the technical maintenance costs are higher in tenament buildings than in apartment owning companies (Tableau 6.2): 19.9% higher when own heating system is utilized and 19.5% higher when district heating system is utilized.

In Fig. 6.1 the average size of building companies in Technical maintenance costs are higher in building companies utilizing own heating system than in buildings with district heating: 8.1% or 2.39 Fmk/LM2/yr higher in apartment owning companies and 8.5% or 2.99 Fmk/LM2/yr higher in tenament building companies (Tableau 6.2).

The trend of costs is the same with the technical maintenance costs of Set B, Tableau 6.3. Technical maintenance costs in building companies with own heating system are 10.1% higher than in buildings with district heating.

In Tableaus 6.2 and 6.3 the district heating corresponds with the centralized maintenance, the own heating system with traditional apartment building maintenance.
The heating costs, however, are higher in buildings with district heating than in buildings when own heating system utilized: in apartment owning companies 5.4% higher and tenament building companies 8.8% higher (Tableau 6.2). The heating costs include then the costs of heating oil when own heating system utilized, and the costs of district heat energy bought from the district heating company. Founding costs of heating installations are excluded.

In Tableau 6.4 there is shown the output of building volume maintained by maintenance personnel in the building companies of Set B. The output of building volume maintained per laborer in a year is higher when district or area heating is utilized than when there is an own heating system. This concerns work based both on full-time basis and on part-time basis. The reason for the increase of maintenance output/laborer is the elimination of practically all heating work, as will shown later. The size of building companies is also large, in general, in companies with district or area heating, and this makes it possible to rationalize the maintenance work in a more effective way.

In Fig. 6.1 the average size of building companies in each locality is shown as a function both types of building companies increase with the size of city. The tenament building companies, in general, are slightly larger than apartment-owning companies (Fig. 6.1). The difference in various sizes of localities is very significant to the building maintenance.
### Tableau 6.1

<table>
<thead>
<tr>
<th></th>
<th>Apartment owning company</th>
<th></th>
<th>Tenament building company</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Own heating system</td>
<td>District heating</td>
<td>Own heating system</td>
<td>District heating</td>
</tr>
<tr>
<td>Technical maintenance costs</td>
<td>31:83</td>
<td>29:44</td>
<td>38:16</td>
<td>35:17</td>
</tr>
<tr>
<td>Water and water cleaning</td>
<td>4:93</td>
<td>4:84</td>
<td>6:52</td>
<td>5:86</td>
</tr>
<tr>
<td>Electricity</td>
<td>3:56</td>
<td>3:16</td>
<td>3:24</td>
<td>3:56</td>
</tr>
<tr>
<td>Insurances</td>
<td>0:75</td>
<td>0:65</td>
<td>0:54</td>
<td>0:66</td>
</tr>
<tr>
<td>Other maintenance costs</td>
<td>1:00</td>
<td>1:60</td>
<td>1:78</td>
<td>2:00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>42:07</strong></td>
<td><strong>39:72</strong></td>
<td><strong>50:29</strong></td>
<td><strong>47:28</strong></td>
</tr>
</tbody>
</table>

### Tableau 6.2
Technical maintenance costs (Fmk/LM2/year) in the buildings of Set A, fiscal year 1975.

<table>
<thead>
<tr>
<th></th>
<th>Apartment owning company</th>
<th></th>
<th>Tenament building company</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Own heating system</td>
<td>District heating</td>
<td>Own heating system</td>
<td>District heating</td>
</tr>
<tr>
<td>Labour costs</td>
<td>11:40</td>
<td>9:51</td>
<td>12:76</td>
<td>10:51</td>
</tr>
<tr>
<td>Heating</td>
<td>13:61</td>
<td>14:34</td>
<td>14:59</td>
<td>15:88</td>
</tr>
<tr>
<td>Inside cleaning</td>
<td>1:41</td>
<td>1:29</td>
<td>2:31</td>
<td>2:29</td>
</tr>
<tr>
<td>Repair costs</td>
<td>5:41</td>
<td>4:30</td>
<td>8:50</td>
<td>6:49</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>31:83</strong></td>
<td><strong>29:44</strong></td>
<td><strong>38:16</strong></td>
<td><strong>35:17</strong></td>
</tr>
<tr>
<td></td>
<td>District heating</td>
<td>Own heating system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------------</td>
<td>------------------</td>
<td>-------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labour costs</td>
<td>6:84</td>
<td>7:92</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating</td>
<td>11:40</td>
<td>15:96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Costs for cleaning and service firms</td>
<td>1:68</td>
<td>0:48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repair costs and costs for repair firms</td>
<td>5:64</td>
<td>3:84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Costs for administration and bookkeeping firms</td>
<td>0:60</td>
<td>0:60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>26:16</td>
<td>28:80</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tableau 6.3

<table>
<thead>
<tr>
<th></th>
<th>Output (BM3/manhour)</th>
<th>Manhour (laborer x year)</th>
<th>Labor costs (Fmk/manhour)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>District heating</td>
<td>Area heating</td>
<td>Own heating</td>
</tr>
<tr>
<td>Full-time basis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance man</td>
<td>6.6</td>
<td>5.2</td>
<td>3.9</td>
</tr>
<tr>
<td>Cleaner</td>
<td>8.1</td>
<td>6.5</td>
<td>7.4</td>
</tr>
<tr>
<td>Manager</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Part-time basis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance man</td>
<td>12.9</td>
<td>14.5</td>
<td>8.8</td>
</tr>
<tr>
<td>Cleaner</td>
<td>15.7</td>
<td>23.3</td>
<td>12.8</td>
</tr>
<tr>
<td>Manager</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Other</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

1) Building-m² maintained by maintenance personnel in a year.
2) Includes janitorial and other maintenance work of general nature.

Tableau 6.4
Output BM3/manhour, annual manhour load per laborer, and labor costs per manhour in the maintenance groups. District and area heating correspond with the centralized maintenance, own heating with the traditional maintenance system. (Office of Statistics, Finland; preliminary statistics for 1975).
Figure 6.1
The size of building companies as a function of locality size. The size of company is given with the number of apartments. Set A, Government of Housing.
2. ANALYSIS FOR THE MODEL OF TOTAL PRODUCTIVITY

The analysis is directed for the calculations of variables in Eq. (4.7) and Eq. (4.12).

2.1 Capital investments

2.11 Capital costs of heating installations

For the comparisons the following two systems will be studied:

(i) Own heating system for 1 to 3 buildings utilizing light heating oil.
(ii) District heating when the heat energy is bought from district heating company.

In comparisons such equipment are excluded which are similar in both systems; like radiators, warm water arrangement inside buildings.

The technical life of both heating systems in supposed to be 20 years. No salvage values are taken into consideration after 20 years.

2.111 Own heating system

The founding costs will be as follows: Eq. 6.1:

\[
A(C_{ho}) = \left(\frac{(a+b+c+d)}{V}\right) \left(\frac{A/P, i=8\%, N=20}{1}\right) \quad \ldots (6.1)
\]

where

- \( A(C_{ho}) \) = annual costs of own heating system, Fmk/BM3
- \( a \) = costs of heating furnaces
- \( b \) = costs of heating burners
- \( c \) = cost of chimneys with their foundings
- \( d \) = costs of warm water reservoir
- \( V \) = volume of buildings, BM3
Then,
a. Heating furnaces: 60 000 Fmk
   - 2 furnaces, à 30 000 Fmk
   - technical life 20 years
   - capacity 350 kW
   - furnace costs include
     - heat transmitter
     - motor ventilator
     - control board
     - pump center
     - installation costs

b. Heating burners: 16 000 Fmk
   - 2 burners, à 8 000 mk + after 10 yrs 32 000 Fmk
   - technical life 10 years when
   - the price of burners is supposed to be 100 % higher than in 1976,
   - à 16 000 mk

c. Chimney: 18 000 Fmk
   - steel chimney, height 12 meters
   - technical life 20 years
   - chimney 12 000 Fmk
   - installation and building costs 6 000 mk

d. Warm water reserver: 20 000 Fmk
   - costs with equipment and instal-
   - lation 20 000 Fmk
   - technical life 20 years

Thus,

\[
A(C_{ho}) = \frac{(60000+16000+[(32000)(P/F,8,10)] +18000+20000)(A/P,8,20)}{10 000}
\]

\[
A(C_{ho}) = 1:31 \text{ Fmk/m3/year}
\]

The interest rate, \( i = 8 \% \), is used because of the long planning horizon, \( N = 20 \) years. Otherwise it should be \( i = 9 \% \).
District heating

The building companies have the following founding costs for district heating:

(i) Costs of joining to the district heating network
   - for this cost the district heating company will build the installations up to
     the heat transmission room but not the facilities in the buildings
   - the cost is supposed to occur once every 20 years.

(ii) Costs of district heat transmission installations in the buildings, Fig. 6.2
   - the technical life is supposed to be 20 years.

The level of joining costs may vary considerably because of the following reasons:
   a. The volume of building
   b. The age of building, purpose of use, and location
   c. Size of locality.

Because of marketing reasons the joining costs of district heating are higher to the new buildings without own heating systems than to old buildings with their own heating installation, Fig. 6.3.

In Tableau 6.5 there are given the founding costs for introducing district heating in fire sizes of apartment building companies. The annual costs for introducing district heating in the buildings has been calculated with Eq. 6.2;

\[ A(C_{hd}) = \frac{(a+b) (A/P,i=8\%, N=20)}{V} \]  

...(6.2)

where

- \( A(C_{hd}) \) = annual cost of introducing district heating, FM/BM3
- \( a \) = joining costs to the district heating network
b = costs of district heat transmission installations in the buildings
V = size of buildings, BM³

Then by using the values of Tableau 6.5:

size = 10 000 m³:
\[ A(C_{hd}) = \frac{58 000 + 34 500}{10 000} \cdot (0.10185) = 0.94 \text{ Fmk/BM³} \]

size = 50 000 m³:
\[ A(C_{hd}) = \frac{173 750 + 165 000}{50 000} \cdot (0.10185) = 0.69 \text{ Fmk/BM³} \]

size = 150 000 m³:
\[ A(C_{hd}) = \frac{490 000 + 480 000}{150 000} \cdot (0.10185) = 0.66 \text{ Fmk/BM³} \]

size = 500 000 m³:
\[ A(C_{hd}) = \frac{1 600 000 + 1 575 000}{500 000} \cdot (0.10185) = 0.65 \text{ Fmk/BM³} \]

size = 1 000 000 m³:
\[ A(C_{hd}) = \frac{3 200 000 + 3 150 000}{1 000 000} \cdot (0.10185) = 0.65 \text{ Fmk/BM³} \]

The costs for building company with size = 300 000 m³ can be approximated to be (Fig. 2):

\[ A(C_{hd}) = 0.66 \text{ Fmk/BM³} \]

In Tableau 6.6 there are shown the differences between annual costs of own heating system installation, A(C_{ho}), and annual costs of district heating installation in the six size categories of building companies.
Figure 6.2
District heating transmission installations in an apartment building company with volume 35 000 BM3.
Figure 6.3
Costs of building company for joining to the district heating in various sizes of joining units. (Prices in 1976).
Figure 6.4
Annual costs for introducing district heating in apartment building companies. Costs (Fmk/BM3/year) given as a function of building company volume (BM3). In calculation of annual cost interest rate \( i = 8 \% \) and planning horizon \( N = 20 \) years has been used. Based on prices in 1976. Actual costs (Fmk/BM3/year) in five size categories are given.
<table>
<thead>
<tr>
<th>Volume of building company, BM³</th>
<th>Average volume of joining units in the building company to be connected to district heating, BM³</th>
<th>Number of joining units to the district heating</th>
<th>Total joining costs for district heating in the building company, Fmk</th>
<th>Cost of district heating transmission installations in the building company, Fmk</th>
<th>Total founding costs for introducing district heating to the building company, Fmk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 000 000 BM³</td>
<td>50 000 BM³</td>
<td>3</td>
<td>173 750 Fmk</td>
<td>3.48 Fmk/BM³</td>
<td>209 230 Fmk</td>
</tr>
<tr>
<td>500 000 BM³</td>
<td>50 000 BM³</td>
<td>3</td>
<td>165 000 Fmk</td>
<td>3.30 Fmk/BM³</td>
<td>201 300 Fmk</td>
</tr>
<tr>
<td>150 000 BM³</td>
<td>50 000 BM³</td>
<td>3</td>
<td>154 000 Fmk</td>
<td>3.15 Fmk/BM³</td>
<td>194 150 Fmk</td>
</tr>
<tr>
<td>50 000 BM³</td>
<td>50 000 BM³</td>
<td>3</td>
<td>145 000 Fmk</td>
<td>3.00 Fmk/BM³</td>
<td>188 500 Fmk</td>
</tr>
<tr>
<td>10 000 BM³</td>
<td>50 000 BM³</td>
<td>3</td>
<td>140 000 Fmk</td>
<td>2.85 Fmk/BM³</td>
<td>183 850 Fmk</td>
</tr>
</tbody>
</table>

Table 6.5: Founding costs for introducing district heating to the building companies in five size categories. Prices in 1976.
### Tableau 6.6

All founding costs (Fmk/BM3/year) of own heating system and district heating (joining costs included). In calculation of annual costs interest rate $i = 8\%$ and planning horizon $N = 20$ years are used.

<table>
<thead>
<tr>
<th>Volume of building company, BM3</th>
<th>$A(C_{ho})$</th>
<th>$A(C_{hd})$</th>
<th>$D = A(C_{ho} - C_{hd})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 000 BM3</td>
<td>1:31</td>
<td>0:94</td>
<td>0:37</td>
</tr>
<tr>
<td>50 000 BM3</td>
<td>1:31</td>
<td>0:69</td>
<td>0:62</td>
</tr>
<tr>
<td>150 000 BM3</td>
<td>1:31</td>
<td>0:66</td>
<td>0:65</td>
</tr>
<tr>
<td>300 000 BM3</td>
<td>1:31</td>
<td>0:66</td>
<td>0:65</td>
</tr>
<tr>
<td>500 000 BM3</td>
<td>1:31</td>
<td>0:65</td>
<td>0:66</td>
</tr>
<tr>
<td>1 000 000 BM3</td>
<td>1:31</td>
<td>0:65</td>
<td>0:66</td>
</tr>
</tbody>
</table>

The annual costs of maintenance service spaces, $A(C_g)$, are calculated as follows (Eq. 6.3):

$$A(C_g) = \left[\frac{d \times y}{V}\right] \times \left[\sum \left(\frac{P}{P_1 + 8\%, N=8}\right)\right] (A/P, i=8\%, N=8)$$

Where:

- $A(C_g)$ = annual costs of maintenance service area measured towards the total volume of building company, Fmk/BM3
- $d$ = demand of service area measured towards the volume of building company (see Fig. 6.5), service-m²/BM3
2.12 Founding costs of maintenance service stations and spaces, $C_s$

There are no norms for building the service spaces of
apartment building maintenance. Separate building com-
panies have planned independently their maintenance ser-
vice buildings.

In Tableau 6.7 there is shown the demand of maintenance
service space in four size categories of building compa-

dies. Table 1 gives the average values and it is based
on interviews in the maintenance companies of 9 cities.
The demand of maintenance service area as a function of
building company size is given in Fig. 6.5.

Fig. 6.6 shows the layout of a typical maintenance ser-
vice space for a building company with volume 300 000 BM3.
In new building areas the maintenance service spaces are
in a special building, in older building areas they are
in the ground floor of apartment buildings.

In Fig. 6.7 there is given the extra costs that caused
by building the maintenance service spaces to the build-
ing companies. The costs of service spaces are meas-
ured towards the total volume of building company (Fmk/
BM3). The building costs of service areas in 1976 are
1 400 Fmk/service-m^2.

The annual costs of maintenance service spaces, $A(C_s)$,
are calculated as follows (Eq. 6.3);

$$A(C_s) = \left( \frac{d \cdot y}{V} \right) - \left[ S \cdot \left( P/F, i=8\%, N=8 \right) \right] \cdot (A/P, i=9\%, N=8) \ldots (6.3)$$

where

$A(C_s)$ = annual costs of maintenance service area measured
towards the total volume of building company, Fmk/BM3.

d = demand of service area measured towards the volume of
building company (see Fig. 6.5), service-m^2/BM3.
\[ y = \text{building costs of service area in 1976, Fmk/m}^2 \]
\[ V = \text{volume of building company} \]
\[ s = \text{salvage value of maintenance service space after 8 years' use; supposed to be 50% of the initial costs.} \]

Thus,

**size = 10 000 BM3:**
\[ A(C_s) = 0 \text{ Fmk/BM3/year} \]

**size = 50 000 BM3:**
\[ A(C_s) = \left\{ (3.70 \text{ Fmk/BM3}) - \left[ (50\%) (3.70 \text{ Fmk/BM3}) \right] (0.5403) \right\} (0.1807) \]
\[ = 0.49 \text{ Fmk/BM3/year} \]

**size = 150 000 BM3:**
\[ A(C_s) = \left\{ (3.20 \text{ Fmk/BM3}) - \left[ (50\%) (3.20 \text{ Fmk/BM3}) \right] (0.5403) \right\} (0.1807) \]
\[ = 0.42 \text{ Fmk/BM3/year} \]

**size = 300 000 BM3:**
\[ A(C_s) = \left\{ (2.25 \text{ Fmk/BM3}) - \left[ (50\%) (2.25 \text{ Fmk/BM3}) \right] (0.5403) \right\} (0.1807) \]
\[ = 0.30 \text{ Fmk/BM3/year} \]

**size = 500 000 BM3:**
\[ A(C_s) = \left\{ (1.55 \text{ Fmk/BM3}) - \left[ (50\%) (1.55 \text{ Fmk/BM3}) \right] (0.5403) \right\} (0.1807) \]
\[ = 0.20 \text{ Fmk/BM3/year} \]

**size = 1 000 000 BM3:**
\[ A(C_s) = \left\{ (1.10 \text{ Fmk/BM3}) - \left[ (50\%) (1.10 \text{ Fmk/BM3}) \right] (0.5403) \right\} (0.1807) \]
\[ = 0.14 \text{ Fmk/BM3/year} \]

The technical life of service spaces is probably much longer than the 8 years' planning horizon. For this reason the salvage value is high.
<table>
<thead>
<tr>
<th>Use of service area:</th>
<th>Size of building company</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20 000 BM³</td>
</tr>
<tr>
<td>1. Administration, management and tenant service</td>
<td>-</td>
</tr>
<tr>
<td>2. Foremen</td>
<td>-</td>
</tr>
<tr>
<td>3. Social spaces for personnel</td>
<td>-</td>
</tr>
<tr>
<td>4. Storage for space parts and repair material</td>
<td>10 m²</td>
</tr>
<tr>
<td>5. Repair and work shops</td>
<td>10 m²</td>
</tr>
<tr>
<td>a. Metal work shop</td>
<td>-</td>
</tr>
<tr>
<td>b. Carpenter and joinery shop</td>
<td>-</td>
</tr>
<tr>
<td>c. Painting room</td>
<td>-</td>
</tr>
<tr>
<td>d. Area work shops for servicemen</td>
<td>-</td>
</tr>
<tr>
<td>6. Control center</td>
<td>5 m²</td>
</tr>
<tr>
<td>7. Machine garages (warm space)</td>
<td>-</td>
</tr>
<tr>
<td>8. Unheated storage for machines and material</td>
<td>25 m²</td>
</tr>
<tr>
<td>Total demand of service area</td>
<td>20 m²</td>
</tr>
</tbody>
</table>

Building costs in 1976¹)
(1 400 Fmk/m²)

|                             | 28 000 Fmk | 280 000 Fmk | 714 000 Fmk | 1 106 000 Fmk |

Service area/building volume service-m²/1 000 BM³
1,00 | 2,67 | 1,38 | 0,79 |

¹) Costs of furniture and other outfit is included in the building costs.

Tableau 6.7
Demand and use of maintenance service area in building companies of 4 size categories.
Figure 6.5 shows the demand of maintenance service area as a function of the size of the building company. Maintenance service area (m²) is measured with respect to each 1,000 BM3 of building volume.
Figure 6.6
Lay-out of a typical maintenance service space for a building company with volume 300,000 BM3: Area of service station 480 square meters.
Costs of maintenance machines, equipment, and tools, $C_m$

For the service and maintenance of buildings the following outfit is required:

- Repair and maintenance machines in the work shops and with repair men: $C_{rm}$ for machine wear, $C_{cp}$ for carpenters' equipment, $C_{pl}$ for plumbers' outfit, $C_{we}$ for welding machines, and $C_{rt}$ for equipment for metal works.
- Machines for outside cleaning, snow removal, and lawns: $C_{oc}$ for costs according to type of machines.
- Transportation vehicles: $C_{tr}$ for license.
- Outfit for inside cleaning: $C_{in}$ for costs.

There is no norm for work machines and other equipment of building maintenance. Especially in small building companies the utilization rate of work machines (machin-hours/workhours of laborers) tends to be very low. For this reason they usually prefer to give a subcontractor for machine works.

Figure 6.7
Extra cost for building maintenance service stations in a building company. Building costs with 1976 prices, 1 400 Fmk per square meter of service area. Costs are measured per total volume (BM3) of the building company.

\[ C_{m} = \frac{1}{2} \left[ \frac{1}{(1+i)^{8}} \left( \frac{1}{(1+i)^{9}} \right) \right] (A/F, i=9\%, N=8) + N \]

\[ A_{(m)} = C(A/C, i=9\%, N=8) \]

\[ N = m + C(A/C, i=9\%, N=8) \]

where

- $A(C_m)$ = annual costs of maintenance machines and other work outfit measured towards the total volume of building company, Fmk/BM3
2.13 Costs of maintenance machines, equipment, and tools, \( C_m \)

For the service and maintenance of buildings the following outfit is required:

- a. Repair and maintenance machines in the work shops and with repair men
  - carpenters' equipment
  - plumbers' outfit, welding machines, and equipment for metal works
- b. Machines for outside cleaning, snow removal and lawns
- c. Transportation vehicles
- d. Outfit for inside cleaning

There is no norm for work machines and other equipment of building maintenance. Especially in small building companies the utilization rate of work machines (machine-hours/workhours of laborers) tends to be very low. For this reason they usually prefer to give a subcontractor for machine works.

In Tableau 6.8 there is shown the demand of work machines and other service outfit in four size groups of building companies. Fig. 6.8 gives the extra costs of work machines and outfit as a function of the size of building company.

\[
M = (0:02 \text{ Pmk}/\text{BM}^3) + [(102) (0:03 \text{ Pmk}/\text{BM}^3)] (3.051) = 0:03 \text{ Pmk}/\text{BM}^3
\]

The annual costs of work machines, equipment and tools can be calculated as follows (Eq. 6.4 and 6.5):

\[
A(C_m) = \left[ \frac{C_{mg}}{S(P/F,i=8\% N=8)} \right] (A/P,i=9\% N=8) + M \quad \ldots(6.4)
\]

when \n
\[
M = m + G(A/G,i=9\% N=8), \quad \ldots(6.5)
\]

where

- \( A(C_m) \) = annual costs of maintenance machines and other work outfit measured towards the total volume of building company, \( \text{Pmk}/\text{BM}^3 \)
$C_m = \text{initial costs of machines and other work outfit in}
\text{1976 measured towards the total volume of building}
\text{company, given in Fig. 6.8}
\text{S = salvage value after 8 years' use; supposed to be 10%}
\text{of initial price in 1976}
\text{M = annual technical operating costs of machines measured}
\text{to the total volume of building, Fmk/BM3. Included}
\text{are fuel, repair and service costs and insurances.}
\text{m = technical operating costs of machines in the first}
\text{year (1976), Fmk/BM3}
\text{C = the increase of technical operating costs of machines}
\text{each year for the 8-year life of machines. The increase}
\text{is supposed to be 10% of the first years' cost.}

It has been supposed, based on the average values, that
the cost of using machines in 1976 is 15 Fmk/machinehour.

The value of M (Eq. 6.4 and Eq. 6.5) using Tableau 6.8
will be for various sizes of building companies, S, as
follows:

90 000 BM3 < S < 200 000 BM3;
M = (0.03 Fmk/BM3) + (10%) (0.03 Fmk/BM3) (3.051) = 0.04 Fmk/BM3

200 000 BM3 < S ≤ 1 000 000 BM3;
M = (0.02 Fmk/BM3) + (10%) (0.03 Fmk/BM3) (3.051) = 0.03 Fmk/BM3

Then, the annual costs of maintenance machines, and outfit, A(C_m), will be for the six size categories of building companies as follows;

size = 10 000 BM3:
A(C_m) = 0 Fmk/BM3/year

size = 50 000 BM3:
A(C_m) = 0 Fmk/BM3/year
size = 150 000 BM3:
\[
A(C_m) = \left\{ (0.85 \text{ Fmk}/\text{BM3}) - \left( 0.10 \text{ Fmk}/\text{BM3} \right) (0.5403) \right\} (0.1807) \\
+ \quad 0.04 \text{ Fmk}/\text{BM3} = 0.18 \text{ Fmk}/\text{BM3/year}
\]

size = 300 000 BM3:
\[
A(C_m) = \left\{ (0.68 \text{ Fmk}/\text{BM3}) - \left( 0.10 \text{ Fmk}/\text{BM3} \right) (0.5403) \right\} (0.1807) \\
+ \quad 0.03 \text{ Fmk}/\text{BM3} = 0.15 \text{ Fmk}/\text{BM3/year}
\]

size = 500 000 BM3:
\[
A(C_m) = \left\{ (0.63 \text{ Fmk}/\text{BM3}) - \left( 0.10 \text{ Fmk}/\text{BM3} \right) (0.5403) \right\} (0.1807) \\
+ \quad 0.03 \text{ Fmk}/\text{BM3} = 0.14 \text{ Fmk}/\text{BM3/year}
\]

size = 1 000 000 BM3:
\[
A(C_m) = \left\{ (0.53 \text{ Fmk}/\text{BM3}) - \left( 0.10 \text{ Fmk}/\text{BM3} \right) (0.5403) \right\} (0.1807) \\
+ \quad 0.03 \text{ Fmk}/\text{BM3} = 0.12 \text{ Fmk}/\text{BM3/year}
\]
<table>
<thead>
<tr>
<th></th>
<th>Size of building company</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90 000 BM3</td>
</tr>
<tr>
<td>Heavy tractors with versatile outfit</td>
<td>100 000 Fmk (1 tractor)</td>
</tr>
<tr>
<td>Mini-tractors with outfit for snow and lawn works</td>
<td>-</td>
</tr>
<tr>
<td>Light trucks for transportation of repair material, snow removal, etc.</td>
<td>-</td>
</tr>
<tr>
<td>Repair equipment, tools and other outfit</td>
<td>10 000 Fmk</td>
</tr>
</tbody>
</table>

|                                | Total costs of maintenance work outfit in 1976 |
|                                | Fmk | Fmk/BM3 |
|                                | 110 000 | 1:22 |
|                                | 115 000 | 0:88 |
|                                | 245 000 | 0:61 |
|                                | 530 000 | 0:53 |

|                                | Operation time of machines (total) |
|                                | 200 | 240 | 560 | 1300 |

|                                | Technical operating costs of machines= (machinehours/year)x(15 Fmk/machinehours) |
|                                | Fmk in 1976 | Fmk/BM3 in 1976 |
|                                | 3 000 | 0:03 |
|                                | 3 600 | 0:03 |
|                                | 8 400 | 0:02 |
|                                | 19 500 | 0:02 |

Tableau 6.8
Demand of maintenance work machines and other outfit in 4 size groups of building companies. Costs with prices in 1976.
2.14 Costs of remote control installations for maintenance equipment, £ 000

The following remote control equipment is recommended for consideration (1976):

(a) Remote warning equipment

Enables the transmission of alarm indications on request. The system permits the equipment, alarm indications which are controlled.

(b) Remote monitoring equipment

Programmed capabilities limited to time-activated logging of alarms by computer systems with diagnostic capability.

The arrangement of the equipment still widely applies to many buildings like ski chalets.

The operator is maintained.

![Graph](image)

Volume of building company, 1000 BM3

Figure 6.8

Extra initial costs of maintenance work machines and equipment measured per total volume of building company (Fmk/BM3).

With prices in 1976.
2.14 Costs of remote control installation and building automation equipment, \( C_v \).

The following remote control alternatives will be taken into consideration (Kettunen, 1976 b; Ross, 1977):

(a) Remote warning control;
   Enables the transmission of alarm or other similar indications on one-way basis: no on-line operations. The system permits remote starting and stopping of equipment, alarm indication and selected temperature indications which are manually run from the central control panel.

(b) Remote monitoring and control system with minimum computer configuration;
   Programmed capabilities of the processing unit are limited to time functions and reporting adjustable analog alarms by comparison of actual building conditions with discrete stored and variable values that are maintained in the limited memory of the processor. The operations are run from a central control station.

(c) Remote control and monitoring by leased telephone lines and equipment from own central control station;
   The capability of using telephone lines for transmission of data and instructions permits the remote building monitoring and operation on a contractual basis or with central control stations in separate building companies. The telephone company has a computer for data handling and transmission on on-line basis. Companies have leased processing outfit in their control stations. Microprocessors are required in building companies, which act as slaves to organize and control the data being fed to the computer.
Large numbers of building companies can be tied in, by means of telephone lines, to the central control station in telephone company. The size of separate building companies tied to the system may be from 10,000 to 600,000 BM3.

This approach permits many sophisticated techniques to be used in small building companies on a rental basis. The systems introduced in telephone companies in 1976 are higher for apartment buildings with rather simple mechanical equipment. The number of warnings is 8/8+4 analog sensors, 8/8+8 analog sensors. In the apartment building companies the system 8 warnings/12 commands is most often utilized. This approach has been investigated.

\[ A(C) = n - S/P, 1, 1-S, 1/2, 1/3, 1/4, 1/5, \ldots \] (6.6)

An older version introduced before 1975 permits only warning transmission by telephone lines but no commands on two-way bases.

(d) Remote control and monitoring with sophisticated computer and building automation;

The central processor computer is capable of performing optimization functions. Permits also automatic remote starting and stopping of equipment, alarm and warning indications, and gives maintenance reports for planning of repair works.

The system is economically feasible only in large building companies.

The remote control of buildings utilizing computers and advanced building automation is very young in Finland. The building of these systems has been started in 1976. There are no financial reports available over the economical results of computerized building control. Therefore,
the effects of building automation and remote control will be calculated separately.

Ross (1977) reports from the USA that an advanced building automation is economically feasible in buildings with at least 400 000 BM3. In buildings with 100 000 to 400 000 BM3 the ability to support an automation system can be solved only through careful engineering study. The computerized building automation with own installation in buildings with less than 100 000 BM3 is economically feasible only very seldom, usually in very complex office buildings. These feasibility limits are higher for apartment buildings with rather simple mechanical equipment and other control objects (Kettunen, 1976b).

2.141 The costs of remote control installation

The costs will be calculated as follows (Eq. 6.6 and 6.7);

\[ A(C_v) = h - S(P/F, i=8\%, 8) (A/P, i=9\%, 8) + M \]  \hspace{1cm} (6.6)

when

\[ M = m + G(A/G, i=9\%, N=8) \]  \hspace{1cm} (6.7)

where

- \( A(C_v) \) = annual costs of remote control installation measured towards the total volume of building company, Fmk/BM3
- \( h \) = founding costs of remote control installation in 1976 measured towards the total volume of building company, Fmk/BM3
- \( S \) = salvage value of installation after 8 years' use: supposed to be 40% of initial price. Obsolescence of computers is taken into account in the salvage value, Fmk/BM3
- \( M \) = operating costs of remote control installations including leases of telephone lines, service and programming of computers, etc., Fmk/BM3
- \( m \) = operating costs of installations in the first year of use (1976), Fmk/BM3
- \( G \) = increase of operating costs each year for the 8-year planning horizon of installations. The increase is supposed to be 10% of the first years' operating cost, Fmk/BM3.
The outfit and costs for the four remote control alternatives are as follows (Tableau 6.9);

(a) Remote warning control for building company for 190 000 BM3;
   - Founding costs: 120 000 Fmk
   - Operating costs: 2 500 Fmk/year
   - The outfit includes: warning control board, cubles with installation costs, energy generator for emergency use, control prints.

(b) Remote control system with minimum computer configuration for 360 000 BM3;
   - Total founding costs: 790 000 Fmk
   - Operating costs: 40 000 Fmk/year
   - The outfit includes:
     - (i) Base system: 570 000 Fmk
       - Central console (120 000 Fmk) including central processing unit, teletype, operator's console, and intercom
     - Hardware installed in buildings (450 000 Fmk) including coaxial cable, multiplexing cabinets, simple sensors and devices
     - (ii) Control points: 220 000 Fmk
       - Including analog and digital sensors and resettable devices

(c) Remote control by leased telephone lines and rented installation in own control station in building company for 360 000 BM3;
   - Total founding costs: 525 000 Fmk
   - Operating costs: 44 000 Fmk/year
   - The outfit includes:
     - (i) Initial costs for hardware in buildings (420 000 Fmk) including microprocessor for each telephone line (35 lines), cables in buildings, sensors and devices. Costs are 12 000 Fmk per buildings with microprocessor.
     - (ii) Initial costs for joining to the telephone network (105 000 Fmk). Joining costs are 3 000 Fmk/telephone line, 35 lines.

Thus, the costs for the four remote control alternatives are:

Tableau 6.9:

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Founding Costs</th>
<th>Operating Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>120 000 Fmk</td>
<td>2 500 Fmk/year</td>
</tr>
<tr>
<td>(b)</td>
<td>790 000 Fmk</td>
<td>40 000 Fmk/year</td>
</tr>
<tr>
<td>(c)</td>
<td>525 000 Fmk</td>
<td>44 000 Fmk/year</td>
</tr>
</tbody>
</table>
(iii) Leased facilities for control station in building company (15,000 Fmk/year). Includes operator's console, teletype and cathode ray tubes.

(iii) Leasing costs for telephone lines (29,000 Fmk/year). Lease costs 840 Fmk/year per telephone line, 35 lines.

The initial costs of the central computer unit in the telephone company are 400,000 Fmk; these costs are included in the joining costs and line leases.

(d) Remote control with sophisticated computer in the building company for 600,000 BM3:
- Total founding costs: 1,800,000 Fmk
- Operating costs: 90,000 Fmk/year

In Fig. 1 the outfit includes:
(i) Computer and central control station (750,000 Fmk) including central processing unit, bulk storage (disc drive), teletype, operator's console, cathode ray tubes, line printer, intercom expenses.
(ii) Hardware installed in buildings (550,000 Fmk) including coaxial cables and multiplexing cabinets.
(iii) Control points (350,000 Fmk) including analag and digital sensors and resettable devices permitting justifiable operations with optimizations.

(iii) Software costs for computer (150,000 Fmk)

No control system
Thus, the annual costs of remote control installation by using Eq. (6.6) and Eq. (6.7) and the unit costs given in Tableau 6.9 are as follows:

No control system
(a) Remote warning control, size 190,000 BM3;

\[ A(C_v) = (0.84 \text{ Fmk}/\text{BM3}) - (0.01 \text{ Fmk}/\text{BM3})(3.051) = 0.84 \text{ Fmk}/\text{BM3} \]

Remote warning control
\[ A(C_v) = 0.14 \text{ Fmk}/\text{BM3/year} \]
(b) Remote control with minimum computer, size 360 000 BM3;
Remote control with leased telephone lines.
\[
A(C_v) = \{(2.19 \text{ Fmk/BM3}) - (40\%) (2.19 \text{ Fmk/BM3}) (0.5403) \} (0.1807) \\
+ \{(0.11 \text{ Fmk/BM3}) + (10\%) (0.11 \text{ Fmk/BM3}) (3.051)\} = 0.45 \text{ Fmk/BM3}
\]

(size 560 000 BM3;)

(c) Remote control by leased telephone lines, size 360 000 BM3/
\[
A(C_v) = \{(1.46 \text{ Fmk/BM3}) - (40\%) (1.46 \text{ Fmk/BM3}) (0.5403) \} (0.1807) \\
+ \{(0.12 \text{ Fmk/BM3}) + (10\%) (0.12 \text{ Fmk/BM3}) (3.051)\} = 0.37 \text{ Fmk/BM3}
\]

(d) Remote control with sophisticated computer, size 600 000 BM3;
\[
A(C_v) = \{(3.00 \text{ Fmk/BM3}) - (40\%) (3.00 \text{ Fmk/BM3}) (0.5403) \} (0.1807) \\
+ \{(0.15 \text{ Fmk/BM3}) + (10\%) (0.15 \text{ Fmk/BM3}) (3.051)\} = 0.62 \text{ Fmk/BM3}
\]

In Fig. 6.9 there are shown for the four remote control alternatives the annual costs of installations (Fmk/BM3) and the technical and economical feasibility as a function of building volume. It has been supposed, based on actual building costs, that the unit costs of founding expenses will decrease 20% when the building volume increases 100%.

Based on Fig. 6.9, the technically and economically feasible remote control systems for the six size categories of building companies will be as follows:

(size 10 000 BM3;)
No control system
\[ A(C_v) = 0 \]

(size 50 000 BM3;)
No control system
\[ A(C_v) = 0 \]

(size 150 000 BM3;)
Remote warning control.
\[ A(C_v) = 0.14 \text{ Fmk/BM3/year} \]
size 300 000 BM3;
Remote control with leased telephone lines.
\[ A(C_Y) = 0.40 \text{ Fmk/BM3/year} \]

size 500 000 BM3;
Remote control with leased telephone lines.
\[ A(C_Y) = 0.34 \text{ Fmk/BM3/year} \]

size 1 000 000 BM3;
Remote control with sophisticated computer configuration.
\[ A(C_Y) = 0.52 \text{ Fmk/BM3/year} \]
<table>
<thead>
<tr>
<th>Type of control</th>
<th>Remote warning control</th>
<th>Remote monitoring and control with minimum computer configuration</th>
<th>Remote monitoring and control by leased telephone lines and equipment from own central control station</th>
<th>Remote control and monitoring with sophisticated computer and building automation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of company</td>
<td>190 000 BM3</td>
<td>360 000 BM3</td>
<td>360 000 BM3</td>
<td>600 000 BM3</td>
</tr>
<tr>
<td>Costs in 1976</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Founding costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Operating costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Unit costs</td>
<td>120 000 Fmk</td>
<td>790 000 Fmk</td>
<td>525 000 Fmk</td>
<td>1 800 000 Fmk</td>
</tr>
<tr>
<td>b) Operating costs</td>
<td></td>
<td>0:84 Fmk/BLM3</td>
<td>2:19 Fmk/BLM3</td>
<td>1:46 Fmk/BLM3</td>
</tr>
<tr>
<td>- Unit costs</td>
<td>2 500 Fmk/yr</td>
<td>40 000 Fmk/yr</td>
<td>44 000 Fmk/yr</td>
<td>90 000 Fmk/yr</td>
</tr>
<tr>
<td>Main influence of remote control</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Labor costs of servicemen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Heating costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Electricity costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tableau 6.9
Four types of remote control systems and their characteristics.
Figure 6.9

Annual costs of five various remote control systems Fmk/BM3/year.

1 = warning control
2 = remote control with leased telephone lines
3 = remote control with minimum computer configuration
4 = remote control with more sophisticated computer and automation
5 = average cost of the systems which have been applied.
The benefits gained by utilizing remote control in buildings, $B$
will be calculated with Eq. (6.8); there are no financial reports available about the consequences of remote control utilization because of the systems have been introduced after 1976.

The benefits have to be evaluated based on the capabilities of control outfit. The estimation attitude has been conservative; the manufacturers refer to much more optimistic and higher profits to be gained by systems.

The benefit of remote control systems can be calculated with Eq. (6.8);

\[ B = L_B + E_B + S + T \]  

(6.8)

where

\[ L_B = L_{Bp} + L_{Bi} + L_{Br} \]  

(6.9)

\[ E_B = E_{Bb} + E_{Bw} \]  

(6.10)

$B$ = annual value of total benefit gained when remote control is utilized in building company, Fmk/EM3/year

$L_B$ = benefits in labor costs, Fmk/EM3/year

$L_{Bp}$ = benefit in labor costs when the servicemen duties on weekends have been eliminated Fmk/EM3/year

$L_{Bi}$ = benefit in labor costs when the extra works outside regular work hours (7 a.m. to 5 p.m.) have been minimized or eliminated; closing of doors, stopping of saunas, general security control, etc.; Fmk/EM3/year

$L_{Br}$ = benefit in labor costs gained by the rationalization of routine maintenance work in regular work hours, Fmk/EM3/year

$E_B$ = benefits in energy costs of heating, Fmk/EM3/year

$E_{Bb}$ = benefits in energy costs by controlling the heating of building space, controlling the inside temperature, air conditioning, ventilation, etc., Fmk/EM3/year

$E_{Bw}$ = benefits in energy costs by controlling the temperature of warm water, Fmk/EM3/year

$S$ = benefits in electricity costs by controlling the lighting in staircases and parking lots, electrical heating of saunas, operation of elevators, machines in cold-storage chambers, etc. Fmk/EM3/year

$T$ = benefits in preventive maintenance of machines and other mechanical assets, Fmk/EM3/year

Thus by Eq. (6.8) the average hourly wage can be calculated with Eq. (6.12);
For the calculation of annual value of benefits (Eq. 6.8) only labor costs (Eq. 6.9) and energy costs (Eq. 6.10) will be taken into account. The benefits in costs of electricity and preventive maintenance could not be satisfactorily justified; the benefits, however, seemed to be undisputable but rather marginal.

In calculations, the annual values of hourly wages and energy costs for the planning horizon of 8 years will be required.

2.151 Average hourly wages

The average hourly wage can be calculated with Eq. (6.11):

\[ w = y + G(A/G, i = 9, 8) \quad \text{...(6.11)} \]

when

\[ G = W \cdot \frac{v}{n} \quad \text{...(6.12)} \]

where

\[ w = \text{average hourly wage including social costs, Fmk/hour, for the 8 years' planning horizon} \]
\[ y = \text{average hourly wage including social costs in 1976, Fmk/hour} \]
\[ G = \text{annual increase in the hourly wage each year for the 8-years' planning horizon. Supposed to be 6\% of the first years' (1976) wage.} \]
\[ W = \text{average monthly compensation for maintenance laborers in 1976, Fmk/month.} \]
\[ v = \text{social security costs paid by building companies} \]
\[ n = \text{number of workhours per month} \]

Thus by Eq. (6.11) and Eq. (6.12) the average hourly wage will be:

\[
w = \left(\frac{(1550 \text{ Fmk/month})(130\%)}{168 \text{ hours/month}}\right) + \left\{6\% \left(\frac{(1550 \text{ Fmk/hour})(130\%)}{168 \text{ hours/month}}\right)\right\} \quad \text{(3.051)}
\]

\[ = 14:20 \text{ Fmk/hour} \]

Then, the average hourly wage in 1976 is \( y = 12:00 \text{ Fmk/hour} \). It is very closed of the statistical values of the set \( B \) if inflation (9 \%) is taken into account:
(11:00 Fmk/hour) x (109 %) = 11:99 Fmk in 1976 (see Tableau 6.4).

According to the official union contracts between maintenance laborers and employers, the hourly wage on week-end duties and evening duties (5 p.m. to 10 p.m.) in 1976 was 2:90 Fmk/hour. Thus the average hourly wage for duties, \( w_d \), to the 8-year planning horizon by Eq. (6.11) will be as follows:

\[
\begin{align*}
  w_c &= (2.90 \text{ Fmk/hour}) \times (130\%) + (6\% \times (2.90 \text{ Fmk/hour}) \times (130\%)) \times (3.051) \\
  &= 4.46 \text{ Fmk/hour}
\end{align*}
\]

By utilizing remote control the work of servicemen duties, \( L_{bp} \) in Eq. (4.2), is supposed to reduce as follows; regularly one servicemen would be required on duty towards each 75 000 BM3 in building companies of any size. When remote control utilized, only one serviceman on duty in the building company will be required and the others can be eliminated.

The use of workhour/BM3 in calculation of \( L_{br} \) in Eq. (4.2) is given in Fig. 6.10.

2.152 Heating costs

The average costs of heating for the 8 years' planning horizon is supposed to be 3:78 Fmk/BM3 (costs of district heating; see Chapter 2.3).

By estimating the reduction of heating costs with heating monitoring, a decrease 1°C in the temperature of buildings equals a reduction of 4% in total heating costs.

2.153 Benefits in labor and heating costs

For the six size categories the benefits, measured as Fmk/BM3/year, by Eq. (6.8) will be as follows; (Tableau 6.10):
Size 10 000 BM3 and 50 000 BM3.
No control system
B = 0

Size 150 000 BM3, warning control system;
B = L_B = L_{Bp} + L_{Bi} + L_{Br}

\begin{align*}
B &= \frac{(1 \text{ duty/yr})(48 \text{ hours/duty})(52 \text{ duties/yr})(4.46 \text{ Fmk/hour})}{150 000 \text{ BM3}} \\
&+ \frac{150 000 \text{ BM3}}{(2 \text{ hours/day})(252 \text{ days/yr})(14.20 \text{ Fmk/hour})} \\
&+ \frac{(4\%)(0.072 \text{ hours/BM3})}{150 000 \text{ BM3}} \\
(14.20 \text{ Fmk/hour}) &= 0.16 \text{ Fmk/BM3/yr}
\end{align*}

The rationalization of labor work (see Fig. 6.11), L_{Br}, is caused only by servicemen.

Size 300 000 BM3, control with leased equipment by telephone lines;
B = L_B + E_B = (L_{Bp} + L_{Bi} + L_{Br}) + (E_{Bp} + E_{Bw})

\begin{align*}
B &= \frac{(3 \text{ duties/yr})(48 \text{ hours/duty})(52 \text{ duties/yr})(4.46 \text{ Fmk/hour})}{300 000 \text{ BM3}} \\
&+ \frac{300 000 \text{ BM3}}{(4 \text{ hours/day})(252 \text{ days/yr})(14.20 \text{ Fmk/hour})} \\
&+ \frac{(5\%)(0.065 \text{ hours/BM3})}{300 000 \text{ BM3}} \\
(14.20 \text{ Fmk/hours}) &= \left[\frac{(3\%)(3.78 \text{ Fmk/BM3})+(0.5\%)(3.78 \text{ Fmk/BM3})}{300 000 \text{ BM3}}\right] \\
&= 0.34 \text{ Fmk}
\end{align*}

The decrease in operating staff, comparable to the reduction in man-hours, is almost the same when computer or control system by telephone lines is utilized. The computer, however, is more capable.

Size 500 000 BM3, control with leased equipment by telephone lines;
B = L_B + E_B = (L_{Bp} + L_{Bi} + L_{Br}) + (E_{Bb} + E_{Bw})
\[
B = \left( \frac{6 \text{duties/yr}}{52 \text{duties/yr}} \right) \left( \frac{48 \text{hours/duty}}{14:20 \text{ Fmk/hour}} \right) \left( \frac{500 \text{ 000 BM3}}{0.065 \text{ hours/BM3}} \right) \\
+ \left( \frac{7 \text{hours/day}}{252 \text{ days/yr}} \right) \left( \frac{14:20 \text{ Fmk/hour}}{0.5\%} \right) \\
+ \left( \frac{3\%}{3:78 \text{ Fmk/BM3}} \right) + \left( \frac{0.5\%}{3:78 \text{ Fmk/BM3}} \right) \\
= 0.37 \text{ Fmk/BM3}
\]

Size 1 000 000 BM3; control with sophisticated computer:

\[
B = L_B + E_B = (L_{Bp} + L_{Bi} + L_{Br1} + L_{Br2}) + (E_{Bp} + E_{Bw})
\]

where

\[L_{Br1} = \text{rationalization of maintenance work by service men}\]

\[L_{Br2} = \text{rationalization and reduction of work by foremen and management personnel (Fig. 6.11)}\]

\[
B = \left( \frac{12 \text{duties/yr}}{52 \text{duties/yr}} \right) \left( \frac{48 \text{hours/duty}}{14:20 \text{ Fmk/hour}} \right) \left( \frac{1 \text{ 000 000 BM3}}{0.043 \text{ hours/BM3}} \right) \\
+ \left( \frac{14 \text{hours/day}}{252 \text{ days/yr}} \right) \left( \frac{14:20 \text{ Fmk/hour}}{0.0144 \times 0.5 \text{ Fmk/BM3}} \right) \\
+ \left( \frac{3\%}{3:78 \text{ Fmk/BM3}} \right) + \left( \frac{2\%}{3:78 \text{ Fmk/BM3}} \right) = 0:48 \text{ Fmk/BM3}
\]

The other benefits when computer utilized are data collection for analysis and management reports, preventive maintenance through anticipation. These benefits, however, are excluded in the comparison.

The decrease in operating staff, comparable to the reduction of labor costs in Tableau 6.10, as a result of improved efficiency is almost the same when computer or control system by telephone lines is utilized. The computer, however, permits more reduction in heating costs with its optimization capabilities.
The labor costs are approximately 15% higher in building companies utilizing their own heating system than with district heating, Tableau 6.11. In both heating systems the labor costs decrease when the volume of building companies utilized. The trend is stronger for buildings with their own heating arrangement utilized. Labor costs are 10% higher in buildings with own heating systems and from 40,000 to 50,000 BM3/year, which can be seen in Tableau 6.11. The savings shown to the use of man-hours/year in building companies of not using the use man-hours, and the labor costs, are approximately 10% in tenement buildings than in apartment building companies. Tableau 6.10 shows the reduction in labor costs in buildings from 50,000 BM3/yr. The 50,000 BM3 (Tableau 6.11) correspond closely to the average number of man-hours/BM3/year (Fig. 6.10). The value of use man-hours/BM3/year, when the cost of the use of district heating has been taken into account, is about 10% lower than the average (6.11). The value of the use man-hours/BM3/year, in Fig. (6.11) can be estimated from Tableau 6.10. The benefits given with Pmk/BM3/year for the 8 years, planning horizon.

<table>
<thead>
<tr>
<th>Size of building company</th>
<th>Remote control installation</th>
<th>Labor costs, L_B</th>
<th>Work end duties, L_Bp</th>
<th>Elimination of extra work, L_Bi</th>
<th>Work rationalization, L_Br</th>
<th>Total benefit Pmk/BM3/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000 BM3</td>
<td>no control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50,000 BM3</td>
<td>computer</td>
<td>0.13</td>
<td>0.05</td>
<td>0.06</td>
<td>0.24</td>
<td>0.08</td>
</tr>
<tr>
<td>150,000 BM3</td>
<td>control by telephone lines</td>
<td>0.11</td>
<td>0.05</td>
<td>0.04</td>
<td>0.16</td>
<td>0.02</td>
</tr>
<tr>
<td>300,000 BM3</td>
<td>control by telephone lines</td>
<td>0.13</td>
<td>0.05</td>
<td>0.06</td>
<td>0.24</td>
<td>0.08</td>
</tr>
<tr>
<td>500,000 BM3</td>
<td>control by telephone lines</td>
<td>0.11</td>
<td>0.05</td>
<td>0.04</td>
<td>0.16</td>
<td>0.02</td>
</tr>
<tr>
<td>1,000,000 BM3</td>
<td>control by telephone lines</td>
<td>0.13</td>
<td>0.05</td>
<td>0.06</td>
<td>0.24</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Tableau 6.10

Benefits gained by utilizing remote control systems in building maintenance, rounding costs excluded. Profits given with Pmk/BM3/year for the 8 years, planning horizon.
Labor costs, $L$

The labor costs are approximately 19% higher in building companies utilizing their own heating system than with district heating, Tableau 6.11. In both heating systems the labor costs decrease when the volume of building company increases; the trend is stronger among buildings with own heating arrangement utilized. Labor costs are 35% higher in buildings with own heating system and from 5 000 to 10 000 BM³ than in buildings with district heating and from 40 000 to 50 000 BM³; this corresponds to the difference between traditional maintenance and to some degree centralized maintenance arrangement having better efficiency or reduced operating staff.

In Fig. 6.10 and Fig. 6.11 there are shown the use of man-hours/BM³/year in building companies of set A. The use of manhours, and the labor costs, are approximately 10% higher in tenament buildings than in apartment owning companies, Tableau 6.11 and Tableau 6.2.

The reduction in labor costs in buildings from 5 000 BM³ to 50 000 BM³ (Tableau 6.11) correspond closely to the decrease of use manhours/BM³/year (Fig. 6.10 and Tableau 6.11) when the effect of district heating has been taken into account.

For calculation of labor costs, $L$, with Eq. (4.9) the average hourly wages, $w$, have been determined with Eq. (6.11) to be $w = 14:20$ Fmk/hour. The value of manhour/BM³/year, $b$ in Eq. (4.9) can be estimated from Fig. 6.10.

Then, for the six size categories of building companies by using Eq. (4.9) the labor costs, $L$, are as follows:

Size 10 000 BM³:

$L = (0.260 \text{ hour/BM³/year})(14:20 \text{ Fmk/hour}) = 3:69 \text{ Fmk/BM³/year}$ when own heating system utilized.
Size 50 000 BM3:

\[ L = (0.218 \text{ hour/BM3/yr})(14:20 \text{ Fmk/hour}) = 3:10 \text{ Fmk/BM3/yr} \]

Size 150 000 BM3:

\[ L = (0.193 \text{ hour/BM3/yr})(14:20 \text{ Fmk/hour}) = 2:74 \text{ Fmk/BM3/yr} \]

Size 300 000 BM3:

\[ L = (0.165 \text{ hour/BM3/yr})(14:20 \text{ Fmk/hour}) = 2:34 \text{ Fmk/BM3/yr} \]

Size 500 000 BM3:

\[ L = (0.147 \text{ hour/BM3/yr})(14:20 \text{ Fmk/hour}) = 2:09 \text{ Fmk/BM3/yr} \]

Size 1 000 000 BM3:

\[ L = (0.137 \text{ hour/BM3/yr})(14:20 \text{ Fmk/hour}) = 1:95 \text{ Fmk/BM3/yr} \]

The remote control system is supposed not to be introduced in any building company. District heating is utilized in all companies but in company with 10 000 BM3.

Example of labor costs by introducing district heating:
The introduction of district heating decreases the work load of servicemen. Let's suppose traditional maintenance system, salaries based on work points, company 10 000 BM3. The work points of servicemen total 100 points: 40 points for heating and 60 points for other works. Work points of heating correspond to the fire area of heating furnace (1 m² = 3 points). When district heating introduced, the work points of heating control will be 6 points and for other works 60 points. Thus, the work points and labor costs of servicemen have reduced \((100 - 66/100) 100 = 34\%\). In buildings with 10 000 BM3 the labor costs of servicemen are about 60\% of all labor costs. Thus, all labor costs have decreased 20,4\% by introducing the district heating. The result corresponds to the values in Tableau 1. Usually by introducing the district heating the building maintenance in the company will be totally reorganized. The example is very common among buildings in city-areas.
### Labour costs

<table>
<thead>
<tr>
<th>Volume of company, 1 000 BM3</th>
<th>A</th>
<th>B</th>
<th>C = ( \frac{A-B}{B} \times 100 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 to 10</td>
<td>11:30</td>
<td>8:11</td>
<td>39</td>
</tr>
<tr>
<td>10 to 20</td>
<td>10:15</td>
<td>8:89</td>
<td>14</td>
</tr>
<tr>
<td>20 to 30</td>
<td>9:72</td>
<td>7:56</td>
<td>29</td>
</tr>
<tr>
<td>30 to 40</td>
<td>9:44</td>
<td>7:35</td>
<td>28</td>
</tr>
<tr>
<td>40 to 50</td>
<td>8:46</td>
<td>7:37</td>
<td>15</td>
</tr>
<tr>
<td>TOTAL</td>
<td>9:95</td>
<td>8:38</td>
<td>19</td>
</tr>
</tbody>
</table>

**Tableau 6.11**

Labour costs Fm/k/LM2 in six size groups of building companies when district heating and own heating system is utilized. Apartment building companies, fiscal years 1975, Set A.

### Size of building company, 1 000 BM3

<table>
<thead>
<tr>
<th>Management personnel and foremen</th>
<th>3/7</th>
<th>20</th>
<th>130</th>
<th>1/260</th>
<th>2/370</th>
<th>1/3/500</th>
<th>1/3/1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel in administration and tenant service</td>
<td>0.0514</td>
<td>0.0450</td>
<td>0.0277</td>
<td>0.0208</td>
<td>0.0146</td>
<td>0.0108</td>
<td>0.0144</td>
</tr>
<tr>
<td>Service and repairmen and janitors</td>
<td>0.2571</td>
<td>0.0900</td>
<td>0.0692</td>
<td>0.0762</td>
<td>0.0438</td>
<td>0.0756</td>
<td>0.0432</td>
</tr>
<tr>
<td>Cleaners for inside cleaning</td>
<td>-</td>
<td>0.0900</td>
<td>0.0837</td>
<td>0.0623</td>
<td>0.0778</td>
<td>0.0612</td>
<td>0.0576</td>
</tr>
<tr>
<td>All personnel</td>
<td>0.3085</td>
<td>0.2250</td>
<td>0.2077</td>
<td>0.1801</td>
<td>0.1557</td>
<td>0.1620</td>
<td>0.1368</td>
</tr>
</tbody>
</table>

1) Tenament building company, 2) utilizing remote control, 3) own heating system

**Tableau 6.12**

Annual use of manhours per building-m³ in various building companies. One manyear is supposed to have 1800 manhours.
Figure 6.10
Use of manhours/BM3/year in 1976. All laborers included. A manyear suppose to total 1 800 hours.

Figure 6.11
Use of manhours in maintenance of apartment building companies in 1976, manhour/BM3/year. A manyear is supposed to total 1 800 manhours. The companies are utilizing district heating.
In Tableau 6.14 there are compared the heating costs between district heating and own heating system in 1975. (Set 1). In 12 cities of Finland the district heating costs of apartment buildings are 8.8% and in apartment-owning communities 5.3% higher than the heating costs by utilizing own heating system. The costs of district heating, however, are the same or little lower than the heating costs of own system in bigger medium-sized cities like Helsinki, Oulu, and Turku. Heinonen and Ilkka (1977) report about the same trend in their statistical study over 279 building companies in Tampere, Finland.

In Fig. 6.12 the heating costs are shown as a function of building volumes. The costs decline when the volume of building company increases. The costs of district heating are higher than the costs of own heating system when the volume of building company, V = 11,000 BM3. The difference is very significant when V = 20,000 BM3. The reason is that companies with district heating are charged for the volume of each joining unit. A company usually has several joining units when the unit price of district heat remains high. If there will be a change in the charging principle between district heating and own heating the costs would be more favourable to the district heating.

In determining $R_0$ for the above equation following simplification will be made. The

Figure 6.11

Use of manhours in maintenance of apartment building companies in 1976, manhour/BM3/year. A manyear is supposed to total 1,800 manhours. The companies are utilizing district heating.
Energy costs of heating, \( R_e \)

In Tableau 6.14 there are compared the heating costs between district heating and own heating system in 1975 (Set A). In 12 cities of Finland the district heating costs in tenement buildings are 8.8% and in apartment-owning companies 5.3% higher than the heating costs by utilizing own heating system. The costs of district heating, however, are the same or little lower than the heating costs of own systems in big and medium-sized cities like Helsinki, Oulu, and Tampere. Heinonen and Ilkka (1977) report about the same trend in their statistical study over 279 building companies in Tampere, Finland.

In Fig. 6.12 the heating costs have been shown as a function of building volume. The costs decline when the volume of building company increases. The costs of district heating are higher than the costs of own heating system when the volume of building company, \( V \geq 11,000 \text{ BMJ} \). The difference is very significant when \( V \geq 20,000 \text{ BMJ} \). The reason is that companies with district heating are charger for the volume of each joining unit. A company usually has several joining units when the unit price of district heat remains high. If there will be a change in the margin principle the cost relation between district heating and own heating would be more favourable to the district heating.

In determining \( R_e \) for the Eq. (4.12) the following simplification will be made, Tableau 6.13;

<table>
<thead>
<tr>
<th>Size</th>
<th>Heating cost Fmk/LM²/year in 1976</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Own heating system</td>
</tr>
<tr>
<td>10,000 BM³</td>
<td>15:50</td>
</tr>
<tr>
<td>50,000 BM³ to</td>
<td>11:00</td>
</tr>
<tr>
<td>1,000,000 BM³</td>
<td></td>
</tr>
</tbody>
</table>

Tableau 6.13

Tableau 6.13 corresponds the heating costs of apartment owning companies in 1976.
The annual heating costs for the 8-year planning horizon can be calculated with Eq. (6.13):

\[ A(R_e) = K + G (A/G, i = 9, N = 8) \eta \]

where:

- \( A(R_e) = \) annual heating costs Fmк/BM3/year for the 8-year planning horizon
- \( K = \) heating costs in 1976 measured with Fmк/LM2/year
- \( G = \) increase in the heating costs each year for the 8-year period. Supposed to be 10\% of the first year's cost (1976)
- \( \eta = \) transformation coefficient Fmк/LM2 to Fmк/BM3 (0.232)

Then for the six size categories the heating costs will be as follows:

**Size 10 000 BM3**;
District or own heating system utilized.

\[ A(R_e) = \{15:50 \text{ Fmк/LM2/yr}\} + \{15:50 \text{ Fmк/LM2/yr}\} (0.051) (0.232) = 4:69 \text{ Fmк/PM3/year} \]

**Size 50 000, 150 000, 300 000, 500 000, and 1 000 000 BM3**;
Own heating system utilized.

\[ A(R_e) = \{11:00 \text{ Fmк/LM2/yr}\} + \{11:00 \text{ Fmк/LM2/yr}\} (0.051) (0.232) = 3:33 \text{ Fmк/PM3/year} \]

**Size 50 000, 150 000, 300 000, 500 000 and 1 000 000 BM3**;
District heating utilized.

\[ A(R_e) = \{12:50 \text{ Fmк/LM2/yr}\} + \{12:50 \text{ Fmк/LM2/yr}\} (0.051) (0.232) = 3:78 \text{ Fmк/PM3/year} \]

In determination of productivity with Eq. (4.12) the own heating system will be taken into consideration while size of company is 10 000 BM3, in other cases the district heating will be utilized.

Tableau 6.14
Heating costs when utilizing district heating and own heating system, Finland 1975 (Government of Housing, Set A).
Future increase in energy costs

In 1973 and 1974 there have been drastical changes in the price of heating oil, Fig. 6.13. In 1975 there have not been essential changes in the prices of heavy oil (used in district heating) or light heating oil (used by own heating systems).

The price of oil in Finland is completely tied to the world prices (the prices in Rotterdam, Netherlands, are followed). In the planning horizon of eight years there may be a stronger increase in the prices than the annual increase of 10% that has been supposed in the calculations. In that case, the district heating in Finland would be less vulnerable than small (own) heating systems, because power plants of district heating are going to use more coal and domestic burning turf.

The power plants of district heating are, in general, very young and their capital costs at the present are rather high. In the future the unit price of district heat will be more competitive with the costs of own heating system because of the inflation declining capital costs of power plants.

<table>
<thead>
<tr>
<th>Area</th>
<th>Cost of heating, Fmk/LM²/year</th>
<th>Own heating system</th>
<th>District heating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helsinki</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A 14:00</td>
<td>15:23</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T 14:16</td>
<td>15:26</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>16:97</td>
<td>15:42</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16:66</td>
<td>16:06</td>
</tr>
<tr>
<td>Jyväskylä</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A 14:61</td>
<td>17:44</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T 16:97</td>
<td>15:42</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>16:06</td>
<td></td>
</tr>
<tr>
<td>Oulu</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A 13:61</td>
<td>14:34</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T 14:59</td>
<td>15:88</td>
<td></td>
</tr>
</tbody>
</table>

A = apartment-owning company
T = tenament building company

Tableau 6.14
Heating costs when utilizing district heating and own heating system. Finland 1975 (Government of Housing, Set A).
Figure 6.12
Annual costs for subcontractors or other firms, $Q$

Annual expenses of machine rent or by using machine firms occur in building companies without own heavy machinery for works in outside areas. The use of outside machine firms is common in building companies with less than 50 000 BM3.

The costs for machine firms will be determined for an average building company with 10 000 BM3 and the expenses Fmk/BM3/year are supposed to be similar in companies with 50 000 BM3.

The costs can be determined with the Eq. (6.14):

$$A(Q) = A(Q)_{m} + C(A/Q)_{1} + 0.8$$

...(6.14)

where

$$A(Q)_{m} = \text{annual costs for machine firms for the 8-year period, Fmk/BM3/year}$$

$$C = \text{annual expenses for machine firms each year for the 8-year period}$$

and is supposed to be 10% of the first year's cost.

Two alternatives will be taken into consideration in determining the costs: (a) Snow clearing and removal with tractors:

$$A(Q)_{t} = \text{average number of operation visits per month in the building area required}$$

...(6.15)

where

$$A(Q)_{t} = \text{average number of operation visits per month in the building area required}$$

Price of heavy (Fmk/cubic meter) and light (Fmk/metric ton) heating oil in Finland from 1946 to 1975.
Annual costs for subcontractors or other firms, $Q$

2.41 Costs for machine firms, $Q_m$

Annual expenses of machine rents or by using machine firms occur in building companies without own heavy machinery for works in outside areas. The use of outside machinery firms is common in building companies with less than 50,000 BM3.

The costs for machine firms will be determined for an average building company with 10,000 BM3 and the expenses Fmk/BM3/year are supposed to be similar in companies with 50,000 BM3.

The costs can be determined with the Eq. (6.14):

$$A(Q_m) = q_m + G(A/G, i = 9, 8) \quad \cdots (6.14)$$

where

$$A(Q_m) = \text{annual costs for machine firms for the 8-year period, Fmk/BM3/year}$$

$$q_m = \text{machine costs for firms in 1976, Fmk/BM3/year}$$

$$G = \text{increase in costs for machine firms each year for the 8-year period. Supposed to be 10\% of the first year's cost (1976).}$$

Two alternatives will be taken into consideration in determining $q_m$ as follows:

(a) Snow ploughing and removal with tractors:

$$q_m = p \cdot t \cdot u \cdot c \cdot V \quad \cdots (6.15)$$

where

$p = \text{average number of operation visits per month in the building company}$

$t = \text{number of months per year the machines are required (usually December to March)}$

$u = \text{average work time of machines per operation visit (hours)}$

$c = \text{machine rent including driver, Fmk/hour}$

$V = \text{volume of building company}$
Then
\[ q_m = \frac{(3 \text{ times/month})(4 \text{ months/yr})(2.5 \text{ hours/time})(70 \text{ Fmk/hour})}{10000 \text{ BM}3} = 0.21 \text{ Fmk}/\text{BM3/yr} \]
\[ A(Q_m) = (0.21 \text{ Fmk}/\text{BM3/yr}) + [(10\%)(0.21 \text{ Fmk}/\text{BM3/yr})](3.051) \]
\[ = 0.27 \text{ Fmk}/\text{BM3/yr} \]

(b) Snow removal with tractors and transportation with trucks to snow dumping-ground:

\[ q_m = \frac{k \cdot t \cdot c}{V} \]
\[ A(Q_m) = q_s + G(a/s, i = 9\%, n = 3) \]

where
- \( k \) = number of snow loads per month in trucks to be transported (distance from 3 to 12 kilometers)
- \( t \) = number of months snow removal and transportation required
- \( c \) = costs of machines, Fmk/load
- \( V \) = volume of company, BM3

Then
\[ q_m = \frac{(15 \text{ loads/month})(4 \text{ months/yr})(60 \text{ Fmk/load})}{10000 \text{ BM3}} = 0.36 \text{ Fmk}/\text{BM3/yr} \]
\[ A(Q_m) = (0.36 \text{ Fmk}/\text{BM3/yr}) + [(10\%)(0.36 \text{ Fmk}/\text{BM3/yr})](3.051) \]
\[ = 0.47 \text{ Fmk}/\text{BM3/yr} \]

The snow removal with transportation is common in city areas with high density of buildings, and without transportation common in suburbs.

For productivity comparisons with Eq. (4.12) the costs of snow removal without transportation (0.27 Fmk/BM3/yr) for the building companies 10 000 BM3 and 50 000 BM3 will be taken into consideration as machine firm costs, \( Q_m \).

The repair costs, in general, are strongly depending on repair operations in the buildings of same age and having any type of maintenance years on contractual basis by repair firms.

Costs for repair and service firms, \( Q_s \)

The repair costs in building companies utilizing their own heating systems are 26% to 31% higher than in companies with district heating, Tableau 6.2. District heating cor-
responds to centralized maintenance arrangement. Thus, it seems that traditionally run companies (operating with own heating system) are obliged to use more repair firms on contractual basis; by district heating (centralized system) the same works can be done by own maintenance personnel.

The extra costs of outside repair firms, \( Q_s \), will be determined only to the building company with 10,000 BM3 and own heating system (traditional maintenance, apartment-owning companies) Eq. (6.17) and Eq. (6.18):

\[
A(Q_s) = q_s + G(A/G, i = 9\%, N = 8) \quad \text{... (6.17)}
\]

when

\[
q_s = (q_{so} - q_{sd})e \cdot \eta \quad \text{... (6.18)}
\]

where:

- \( A(Q_s) \) = annual extra costs for repair work in traditional maintenance compared to centralized maintenance arrangement for the 8-year's planning horizon, Fm/k/BM3/yr
- \( q_s \) = extra cost of repair work in traditional maintenance compared centralized maintenance, Fm/k/BM3/year in 1976
- \( G \) = increase of costs for repair firms each year for the 8-year's planning horizon beginning in 1976; supposed to be 10\% of the first year's cost
- \( q_{so} \) = repair costs when own heating system utilized in 1975, Fm/k/LM2/year (Tableau 6.2)
- \( q_{sd} \) = repair costs when district heating system utilized in 1975, Fm/k/LM2/year (Tableau 6.2)
- \( e \) = inflation coefficient between years 1975 and 1976 (1.09)
- \( \eta \) = transformation coefficient of costs, Fm/k/LM2 to Fm/k/BM3, (0.232 l/m).

Then

\[
q_s = (5.41 \text{ Fm/k/LM2} - 4.30 \text{ Fm/k/LM2})(1.09)(0.232) = 0.28 \text{ Fm/k/BM3/yr}
\]

\[
A(Q_s) = (0.28 \text{ Fm/k/BM3/yr}) + \left[ (10\%)(0.28 \text{ Fm/k/BM3/yr}) \right](3.051) = 0.37 \text{ Fm/k/BM3/yr}
\]

The repair costs, in general, are strongly depending on the age of buildings. The quantity of repair operations in the buildings of same age and having any type of maintenance system. Large building companies, however, have special personnel for repair works and preventive maintenance. In small companies these works are done in intervals of several years on contractual basis by repair firms.
CHAPTER VII: FINDINGS AND APPLICATIONS

1. DETERMINATION OF MAINTENANCE PRODUCTIVITY, $P_T$

The productivity of building maintenance system, $P_T$, with the Eq. (4.12) will be determined with and without utilization of remote control arrangement and building automation. Productivities will be calculated for the six size categories of building companies: 10 000, 50 000, 150 000, 300 000, 500 000 and 1 000 000 BM3.

The form of Eq. (4.4) will be used as follows Eq. (7.1) (the influence of remote control is included, Tableau 7.1):

\[
\frac{1}{P_T} = \frac{1}{0} + \frac{1}{0} + \frac{1}{0} + \frac{1}{0} \quad \ldots(7.1)
\]

The values of variables in Tableau 1 have been calculated as annual unit costs, Fmk/BM3/year. Therefore Eq. (7.1) can be given with Eq. (7.2) and $P_T$ can be determined with Eq. (7.3);

\[
\frac{1}{P_T} = \frac{1}{C} + \frac{1}{L} + \frac{1}{R} + \frac{1}{Q} - \frac{1}{B} \quad \ldots(7.2)
\]

When the remote control and building automation have not been introduced (variables $C$, $L$, $R$, $Q$ and $B$ excluded in Tableau), productivity of maintenance, $P_{T1}$, calculated in similar way, will be as follows;

\[
P_T = \frac{1}{C+L+R+Q-B} \quad \ldots(7.3)
\]

Then, by using the values given in Tableau 7.1 the productivity of maintenance, $P_T$, will be as follows:

**Size 10 000 BM3:**

\[
P_T = \frac{1}{0.94 \text{ Fmk/BM3} + 3.69 \text{ Fmk/BM3} + 4.69 \text{ Fmk/BM3} + 0.64 \text{ Fmk/BM3} - 0} = 0.1004 \text{ BM3/Fmk}
\]
Size 50 000 BM3;

\[ P_T = \frac{1}{1:18 \text{ Fmk/BM3} + 3:10 \text{ Fmk/BM3} + 3:78 \text{ Fmk/BM3} + 0:27 \text{ Fmk/BM2} - 0} \]

\[ = 0.1200 \text{ BM3/Fmk} \]

Size 150 000 BM3;

\[ P_T = \frac{1}{1:40 \text{ Fmk/BM3} + 2:74 \text{ Fmk/BM3} + 3:78 \text{ Fmk/BM3} + 0:16 \text{ Fmk/BM3}} \]

\[ = 0.1289 \text{ BM3/Fmk} \]

Size 300 000 BM3;

\[ P_T = \frac{1}{1:51 \text{ Fmk/BM3} + 2:34 \text{ Fmk/BM3} + 3:78 \text{ Fmk/BM3} + 0:36 \text{ Fmk/BM3}} \]

\[ = 0.1372 \text{ BM3/Fmk} \]

Size 500 000 BM3;

\[ P_T = \frac{1}{1:33 \text{ Fmk/BM3} + 2:09 \text{ Fmk/BM3} + 3:78 \text{ Fmk/BM3} + 0:37 \text{ Fmk/BM3}} \]

\[ = 0.1464 \text{ BM3/Fmk} \]

Size 1 000 000 BM3;

\[ P_T = \frac{1}{1:43 \text{ Fmk/BM3} + 1:95 \text{ Fmk/BM3} + 3:78 \text{ Fmk/BM3} + 0:48 \text{ Fmk/BM3}} \]

\[ = 0.1497 \text{ BM3/Fmk} \]

When the remote control and building automation have not been introduced (variables \( C_v \) and \( B \) excluded in Tableau 7.1), the productivity of maintenance, \( P_{T1} \), calculated in similar way, will be as follows:

size 10 000 BM3; \( P_{T1} = 0.1004 \text{ BM3/Fmk} \)
size 50 000 BM3; \( P_{T1} = 0.1200 \text{ BM3/Fmk} \)
size 150 000 BM3; \( P_{T1} = 0.1285 \text{ BM3/Fmk} \)
size 300 000 BM3; \( P_{T1} = 0.1383 \text{ BM3/Fmk} \)
size 500 000 BM3; \( P_{T1} = 0.1458 \text{ BM3/Fmk} \)
size 1 000 000 BM3; \( P_{T1} = 0.1506 \text{ BM3/Fmk} \)
Thus, it can be seen that the effect of remote control is very marginal in the total productivity of building maintenance. The probable benefits of remote control have been estimated conservatively while statistical data not available; the real savings in labor, heating and electricity costs may become higher.

In Fig. 7.1 the total productivity of building maintenance, P_T, with Eq. (4.12), has been shown as a function of building volume. The increase of productivity is very fast up to the building volume of 500 000 BM3 and rather moderate after that limit. The increase of P_T from 10 000 BM3 to 500 000 BM3 is 45.8% and from 500 000 BM3 to 1 000 000 BM3 2.3%.

In each six size categories of building companies the ratio C/L in Eq. (8) is C/L < 1, or C < L (capital investment < labor costs). In Fig. 7.2 the ratio C/L is shown as a function of building volume. The value 0.25 ≤ C/L ≤ 0.73 informs that the productivity of maintenance is labor force oriented in every six size categories. However, the degree of labor force orientation decreases considerably when the size of building company increases, especially by remote control utilization.
<table>
<thead>
<tr>
<th>Variables</th>
<th>10 000 BM3</th>
<th>50 000 BM3</th>
<th>150 000 BM3</th>
<th>300 000 BM3</th>
<th>500 000 BM3</th>
<th>1 000 000 BM3</th>
</tr>
</thead>
<tbody>
<tr>
<td>C = Capital investments</td>
<td>0:94</td>
<td>0:69</td>
<td>0:66</td>
<td>0:65</td>
<td>0:65</td>
<td>0:65</td>
</tr>
<tr>
<td>C&lt;sub&gt;h&lt;/sub&gt; = Heating installations</td>
<td>0</td>
<td>0:49</td>
<td>0:42</td>
<td>0:30</td>
<td>0:20</td>
<td>0:14</td>
</tr>
<tr>
<td>C&lt;sub&gt;s&lt;/sub&gt; = Maintenance service spaces</td>
<td>0</td>
<td>0</td>
<td>0:18</td>
<td>0:15</td>
<td>0:14</td>
<td>0:12</td>
</tr>
<tr>
<td>C&lt;sub&gt;m&lt;/sub&gt; = Maintenance machines and tools</td>
<td>0</td>
<td>0</td>
<td>0:14</td>
<td>0:40</td>
<td>0:34</td>
<td>0:52</td>
</tr>
<tr>
<td>C&lt;sub&gt;v&lt;/sub&gt; = Remote control installations</td>
<td>0:94</td>
<td>1:18</td>
<td>1:40</td>
<td>1:51</td>
<td>1:33</td>
<td>1:43</td>
</tr>
<tr>
<td>L = Labour costs</td>
<td>3:69</td>
<td>3:10</td>
<td>2:74</td>
<td>2:34</td>
<td>2:09</td>
<td>1:95</td>
</tr>
<tr>
<td>Q = Costs for subcontractors</td>
<td>0:27</td>
<td>0:27</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Q&lt;sub&gt;m&lt;/sub&gt; = Machine rents for firms</td>
<td>0:37</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Q&lt;sub&gt;s&lt;/sub&gt; = Extra costs for repair firms</td>
<td>0:64</td>
<td>0:27</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>I = Total costs for input of productivity</td>
<td>9:96</td>
<td>8:33</td>
<td>7:92</td>
<td>7:63</td>
<td>7:20</td>
<td>7:16</td>
</tr>
<tr>
<td>B = Benefits gained by the remote control</td>
<td>0</td>
<td>0</td>
<td>0:16</td>
<td>0:34</td>
<td>0:37</td>
<td>0:48</td>
</tr>
<tr>
<td>(I-B) = Reduced input</td>
<td>9:96</td>
<td>8:33</td>
<td>7:76</td>
<td>7:29</td>
<td>6:83</td>
<td>6:68</td>
</tr>
</tbody>
</table>

Table 7.1
Values of input variables in the measurement of maintenance productivity, Fmk/BM3/year.
Figure 7.1
Total productivity of apartment building maintenance, $P = \text{BM}/\text{Fmk/yr}$, as a function of building volume.
There are three principal models of apartment maintenance use in Finland:

(a) The traditional apartment building maintenance system with conventional tools and methods. The building companies operate as small maintenance units using their own maintenance organisations.

(b) The centrally run apartment maintenance organisation which uses its own technical maintenance teams and which does not use intensive apartment building management.

(c) The organisation of maintenance exploiting the maintenance services of specialized firms: the building companies operate as small, administratively active units.

In the cases overlapping these forms are relatively small in number.

In evaluating different apartment building maintenance techniques, organisations, and maintenance work the following five phases were compared:

Phase 0: The heating system in which there is a heating installation using light fuel oil; one unit serves a single building or is otherwise small. The traditional caretaker system is applied in maintenance work. The administrative maintenance unit is a small entirety or a unit.

Phase II: The size of the maintenance group has been grown so that it is characteristic like a territorial maintenance system. Machinery has been increased, inside cleaning work has been rationalized compared with traditional maintenance.

Figure 7.2

Ratio C/L (capital investments/labor costs) of total maintenance productivity as a function of building volume.
2. PRODUCTIVITY AND COST COMPARISONS OF THE PRINCIPAL MAINTENANCE METHODS

There are three principal models of apartment maintenance use in Finland:

(a) The traditional apartment building maintenance system with conventional tools and methods. The building companies operate as small maintenance units using their own maintenance organizations.

(b) The centrally run apartment maintenance organization which uses its own technical maintenance assets and which takes care of extensive apartment building load.

(c) The organization of maintenance exploiting the maintenance services of specialized firms: the building companies operate as small, administratively active units.

The cases overlapping these forms are relatively small in number.

In evaluating different apartment building maintenance techniques, organizations, and the productivity of maintenance work the following five phases were compared:

Phase 0; Traditional maintenance system in which there is a heating installation using light fuel oil; one unit serves a single building or is otherwise small. The traditional caretakers system is applied in maintenance work. The administrative maintenance unit is a small entirety or a unit which is cumulatively composed of them.

Phase I; The maintenance unit uses the services of a district heating, heating work is entirely eliminated.

Phase II; The size of the maintenance group has been grown so that it is characteristic like a territorial maintenance system. Machinery has been increased, inside cleaning work has been rationalized compared with traditional maintenance.
Phase III; Repair work of the maintenance group, organization of the repair work and technical arrangements have been systematized and centralized.

Phase IV; Remote control and advanced building automation has been introduced to the centralized apartment building company utilizing servicemen system.

The transition from phase 0 to phase III means the same as transition from the traditional maintenance to the centrally run apartment maintenance organization.

As a rule computerized building automation belongs to rationalizing that follows the phase III, the presupposition of which is the accomplishing of central features of the phases 0-III in the maintenance group.

The unit costs (Fmk/BM3/year) will be determined with Tableau 7.1. For the five phases the maintenance productivity, $P_T$, has been determined in the chapter 2.5 when the following preconditions are given based on the field study.

Phase 0; size of company is 10 000 BM3

Productivity is: $P_T = 0.10$ BM3/Fmk

Costs $^1$ of technical maintenance: $I = 0.96$ Fmk/BM3/year

Phase I; size of company from 10 000 to 50 000 BM3

Productivity is: $0.10 \leq P_T \leq 0.12$ BM3/Fmk

Costs of technical maintenance: $0.05 < I < 8.33$ Fmk/BM3/yr

Phase II; size of company from 150 000 to 300 000 BM3

Productivity is: $0.13 \leq P_T \leq 0.14$ BM3/Fmk

Costs of technical maintenance: $7.92 > I > 7.63$

---

1) The same value as the term I or (I-B) in Tableau 6.15.
Phase III; size of company from 300 000 to 500 000 BM3
Productivity is: $0.14 \leq P_T \leq 0.15 \text{ BM3/Fmk}$
Costs of technical maintenance: $7.63 > I > 7.20 \text{ Fmk/BM3/yr}$

Phase IV; size of company from 500 000 to 1 000 000 BM3
Productivity is: $P_T = 0.15 \text{ BM3/Fmk}$
Costs of technical maintenance: $6.83 > I > 6.68 \text{ Fmk/BM3/yr}$

By comparing the average values of productivity, $P_T$, and technical maintenance costs with indices, when Phase $0 = 100$, it will be as follows:

<table>
<thead>
<tr>
<th>Phase</th>
<th>Total productivity (BM3/Fmk)</th>
<th>Costs of technical maintenance (Fmk/BM3/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 0</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Phase I</td>
<td>110</td>
<td>87</td>
</tr>
<tr>
<td>Phase II</td>
<td>135</td>
<td>78</td>
</tr>
<tr>
<td>Phase III</td>
<td>145</td>
<td>74</td>
</tr>
<tr>
<td>Phase IV</td>
<td>150</td>
<td>68</td>
</tr>
</tbody>
</table>

Thus, by transition from the Phase 0 (traditional) to Phase III (centralized maintenance) the total productivity of apartment maintenance has increased 45% and the annual costs of technical maintenance have declined by 26%. The more centralization and advanced automation causes that transition from Phase III to Phase IV increases productivity only marginally but at the same time the technical maintenance costs decline by 8% or (0.50 to 0.80 Fmk/BM3/year).

The overall increase in productivity between Phases 0 and Phase IV is 50% while the maintenance costs decline 32%.

In general, the productivity increases and the costs decline in every development phases (Phases 0-I-II-III-IV).
The increase of productivity is highest between Phase I and Phase II. This is the same than introducing centralized maintenance (Phase II).

THE CONSEQUENCES OF THE APARTMENT MAINTENANCE DEVELOPMENT IN FINLAND

The difference in the technical maintenance costs between Phase 0 (traditional) and Phase III (centralized maintenance) is as follows;

\[
\text{Difference} = (9.96 - 7.20) \text{ Fmk/BM3/year} = 2.76 \text{ Fmk/BM3/yr in Finland.}
\]

or

\[
(2.76 \text{ Fmk/BM3/yr}) \frac{1}{\eta} = 11.89 \text{ Fmk/LM2/year}
\]

An average apartment in Finland totals 64 LM2 (Statistics Government of Housing, Finland). Thus the theoretical saving by introducing the centralized maintenance would mean to an average apartment a decrease in the housing costs as follows;

\[
(11.89 \text{ Fmk/LM2/year}) \times (64 \text{ LM2}) = 760.69 \text{ Fmk/year}
\]

or

\[
(760.69 \text{ Fmk/year}) / 12 \text{ months} = 63.39 \text{ Fmk/month}
\]

For the calculation of total saving in Finland by introducing the centralized apartment maintenance, the apartment maintenance load are calculated in six size categories of localities, Tableau 7.2. In these localities the possible savings in technical maintenance costs have been estimated by taking into account the present use of existing centralized maintenance systems.

In Tableau 7.3 there are shown the total savings in apartment maintenance costs which are to be achieved in Finland by the continuous centralization of apartment maintenance.
(existing centralized systems excluded, based on Tableau 7.2). The estimation is rather rough. The savings in the technical maintenance costs would total 122,150,000 Fmk/year. When localities and built-up areas with less than 5,000 people are excluded. Supposing that 20% of the apartment building companies utilizing traditional maintenance method will never join the centralized systems (unfavourable conditions administratively independent, strong old traditions of maintenance) the annual saving in Finland would be about 100 million Fmk per year. This equals the same as building of 1,000 new apartments every year.

Thus, the nationwide introduction of centralized apartment maintenance method is economically very profitable in Finland.

<table>
<thead>
<tr>
<th>Tableau 7.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apartment maintenance load and estimated savings in technical maintenance costs (Fmk/year) in various locality categories.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tableau 7.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apartment maintenance load and estimated savings in technical maintenance costs (Fmk/year) in various locality categories.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Locality area</th>
<th>Maintenance load</th>
<th>Savings (Fmk/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) in city area</td>
<td>10,000</td>
<td>1,200</td>
</tr>
<tr>
<td>b) outside city area (suburbs)</td>
<td>10,000</td>
<td>1,000</td>
</tr>
<tr>
<td>c) total in locality (10,000 Fmk)</td>
<td>20,000</td>
<td>2,200</td>
</tr>
</tbody>
</table>

1) Equivalent building has 10,500 m² and 40 apartments.
<table>
<thead>
<tr>
<th>Row n:o</th>
<th>Size of locality (1,000 people)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>1. Actual average size of maintenance group, (apartments/company)</td>
<td>17</td>
</tr>
<tr>
<td>2. Actual number of apartment building companies in the locality</td>
<td>20</td>
</tr>
<tr>
<td>3. Apartment maintenance load in locality a) apartments</td>
<td>340</td>
</tr>
<tr>
<td>b) equivalent buildings ¹)</td>
<td>9</td>
</tr>
<tr>
<td>4. Apartment maintenance load of locality in the city area a) % of all buildings</td>
<td>100</td>
</tr>
<tr>
<td>b) number of buildings ¹)</td>
<td>9</td>
</tr>
<tr>
<td>5. Apartment maintenance load of locality outside city area (in suburbs) a) % of all buildings</td>
<td>0</td>
</tr>
<tr>
<td>b) number of buildings ¹)</td>
<td>0</td>
</tr>
<tr>
<td>6. Number of apartment maintenance areas in the locality (in suburbs)</td>
<td>0</td>
</tr>
<tr>
<td>7. Number of buildings ¹) per maintenance area in the locality (in suburbs)</td>
<td>0</td>
</tr>
<tr>
<td>8. % of apartment buildings in the city area of locality belonging to centralized systems</td>
<td>0</td>
</tr>
<tr>
<td>9. % of apartment buildings outside the city area (in suburbs) of locality belonging to centralized systems</td>
<td>0</td>
</tr>
<tr>
<td>10. Actual savings in maintenance costs of locality by taking into account the use of existing centralized systems a) in city area</td>
<td>149</td>
</tr>
<tr>
<td>b) outside city area (suburbs)</td>
<td>0</td>
</tr>
<tr>
<td>c) total in locality (1,000 Fmk)</td>
<td>149</td>
</tr>
</tbody>
</table>

¹) Equivalent building has 10,500 m² and 40 apartments.

Tableau 7.2
Apartment maintenance load and estimated savings in technical maintenance costs (Fmk/year) in various locality categories.
<table>
<thead>
<tr>
<th>Size category of the locality (1 000 people)</th>
<th>Number of localities</th>
<th>Average saving in apartment maintenance costs in the locality (1 000 Fmk)</th>
<th>Total savings in apartment maintenance costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 000</td>
<td>1</td>
<td>25 500</td>
<td>25 500</td>
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<tr>
<td>150 000</td>
<td>2</td>
<td>7 500</td>
<td>15 000</td>
</tr>
<tr>
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<td>31 500</td>
</tr>
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<td>9 500</td>
</tr>
<tr>
<td>30 000</td>
<td>30</td>
<td>1 160</td>
<td>34 800</td>
</tr>
<tr>
<td>5 000</td>
<td>39</td>
<td>150</td>
<td>5 850</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>84</strong></td>
<td></td>
<td><strong>122 150</strong></td>
</tr>
</tbody>
</table>

Tableau 7.3

**Total savings in apartment maintenance costs in Finland.**

The consequences of remote control of buildings. The initial costs of remote control installation may be relatively high compared with other founding costs of maintenance. For this reason the building automation should be studied in a more detailed way.

The training and costs of training of maintenance personnel for the specialized maintenance works should be investigated. Especially, large apartment building companies report that the lack of proper training hampers the effective specialisation on maintenance.

In Finland there is no central or national organisation for apartment building organisations. The building companies are not economically feasible for fundamental research and development work in the maintenance area. A study should be done in order to investigate the possibility to arrange a central organisation for the development of apartment building maintenance.
RECOMMENDATIONS FOR FURTHER RESEARCH

In this paper the productivity of the technical building maintenance operations by using the Eq.(4.13) has not been investigated. However, the measurement of operative productivity might give more accurate information about the characteristics of various maintenance methods. The investigation should be done so that the results could be compared with the total productivity of maintenance (Eq. 4.12).

The remote control with computers and the advanced building automation is very young in Finland. There is no statistical information about the effects after computerized building automation has been introduced. Also in literature there cannot be found relevant references to the consequences of remote control of buildings. The initial costs of remote control installation may be relatively high compared with other founding costs of centralized maintenance. For this reason the building automation facilities and the possible benefits when utilizing remote control should be studied in a more detailed way.

Remote building companies and also nationwide to national economy. By transition from traditional maintenance
The training and costs of training of maintenance personnel for the specialized maintenance works should be investigated. Especially large apartment building companies report that the lack of proper training hampers the effective specialization on maintenance.

In Finland there is no central or national organization for apartment building organizations. The building companies are not economically feasible for fundamental research and development work in the maintenance area. A study should be done in order to investigate the possibility to arrange a central organization for the development of apartment building maintenance.
SUMMARY AND CONCLUSIONS

The main objectives of this study have been:
- investigate the total productivity of building maintenance among basic maintenance models
- differences in the technical maintenance costs for the principal maintenance models
- study the various heating systems and remote control arrangements
- investigate the extra costs of equipment and facilities when introducing centralized and rationalized apartment maintenance model in comparison with the traditional maintenance model.

All the objectives could have been defined or investigated in detail.

For the measurements a model for total productivity of technical apartment maintenance was developed. The model was evaluated by a statistical field study in Finland. It was noticed that the centralization of apartment building maintenance is highly profitable both for separate building companies and also nationwide to national economy. By transition from traditional maintenance method to the centralized maintenance model the total productivity of apartment increased 45% and the annual costs of technical maintenance declined 26%.

Between the thoroughly traditional and specialized maintenance utilizing advanced building automation the overall increase in productivity is 50% while the maintenance costs decline 32%.

The effect of remote control was rather marginal in the productivity of building maintenance. It shall be emphasized that the probable benefits of building automation have been estimated conservatively while statistical cost data not available.
The heating, service station and remote control installations have the highest initial costs in founding of centralized maintenance. The benefits gained with maintenance assets introduced are higher than their founding costs. As in some print-outs of the Set A.

The annual costs in an apartment building company connected to centralized maintenance are about 760 Fmk/year less than in an apartment operated with traditional maintenance method. In Finland the annual saving in the maintenance of all apartment buildings would total some 100 million Fmk/year if centralized maintenance is utilized in a high degree.

Survey over the apartment building maintenance in various countries showed that national or large local organizations for building maintenance are rather common in other countries than Finland. However, the research and development in the building maintenance have not been large in any country so far.
APPENDICES

Appendix 1: Some print-outs of the Set A.

Appendix 2: Three pages as an example of the Set B questionnaire.
Appendix 1  Some print-outs of the Set A
### Appendix 1

Some print-outs of the Set A
<table>
<thead>
<tr>
<th>VUOSI</th>
<th>MAINTENANCE COSTS Fu (m²/year)</th>
<th>Apartment-owning companies</th>
<th>own heating system</th>
</tr>
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<tbody>
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<td></td>
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Several years:
- YHTEENSÄ - 44.47
- USEITA - 43.34

Total:
- 1949-54: 42.08
- 1955-59: 43.32
- 1966-69: 43.32
- 1970-74: 43.32

Average:
- 1949-74: 43.98
- 1955-59: 43.98
- 1966-69: 43.98
- 1970-74: 43.98
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<th>YHTEENSÄ</th>
<th>LAND-OWNING COMPANY</th>
<th>YHTEENSÄ</th>
<th>LAND-OWNING COMPANY</th>
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<td>VUOSI</td>
<td>VUKRATÁL</td>
<td>TAPA BOL</td>
<td>YKUNTA</td>
<td>VUKRATÁL</td>
<td>YKUNTA</td>
</tr>
<tr>
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<td>-------------</td>
<td>-------</td>
<td>------------</td>
<td>--------</td>
<td>--------</td>
<td>------------</td>
<td>--------</td>
</tr>
</tbody>
</table>

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<th>TAMPERE</th>
<th>PORI</th>
<th>LAHTI</th>
<th>LAPPEENRANTA</th>
<th>JYVASKYLA</th>
<th>VAASA</th>
<th>KUOPIO</th>
<th>DULU</th>
<th>KAJAANI</th>
<th>ROVA-NIEMI</th>
<th>KESKI-MARAKKA</th>
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<td>1.10</td>
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<td>-</td>
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<td>0.03</td>
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<td>0.07</td>
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<td>2.71</td>
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</tr>
</tbody>
</table>

Note: The table represents maintenance costs in localities for 1975-1976 in Finland. The costs are listed in Finnish and include various categories such as labor, social costs, fringe benefits, heating, water, electricity, valuation, insurance, repair, and other expenses. The figures are given in thousands of Finnish marks (MK).
<table>
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<th>Social costs, sh.</th>
<th>Total working hours</th>
<th>Total cost, sh.</th>
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Land tax | TONTIN VUOKRA | 4.56 | 0.79 | 5.21 | 1.17 | - | - | 0.54 | 2.08 | 2.96 | 2.55 | 0.62 | 1.48 | 3.42 |
Other tax | MUUT VUOKRA | 0.08 | - | 0.06 | - | - | - | - | 0.12 | - | - | 0.07 | 0.05 |

HOITOMENOT JA TONTIN VUOKRA YHTEENSÄ | 58.39 | 48.36 | 47.40 | 49.95 | 42.35 | 73.68 | 46.13 | 41.68 | 52.77 | 48.63 | 54.72 | 53.33 | 53.72 |
HOITOMENOT JA VUOKRA/RA | 4.87 | 4.03 | 3.96 | 4.16 | 3.53 | 6.14 | 3.84 | 3.47 | 4.41 | 4.05 | 4.56 | 4.45 | 4.48 |
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**Labor Costs (TMK/M²):**
- 5 000: 10.12, 21.85, 12.00, 25.67, 10.15, 23.61, 9.43, 24.05, 9.44, 21.90, 8.46, 21.72, 7.78, 21.13, 9.75, 23.64
- 10 000: 1.38, 2.98, 1.60, 3.44, 1.55, 3.61, 1.36, 3.34, 1.34, 3.12, 1.28, 3.30, 1.22, 3.32, 1.45, 3.45
- 20 001: 0.41, 0.89, 0.09, 0.20, 0.02, 0.04
- 30 001: 17.54, 37.89, 16.03, 36.40, 14.52, 33.80, 12.27, 30.37, 12.17, 28.23, 10.48, 26.90, 9.91, 26.92, 13.61, 32.34
- 40 001: 2.46, 5.31, 2.73, 6.21, 2.63, 6.11, 2.86, 7.09, 3.29, 7.62, 2.97, 7.63, 2.44, 6.64, 2.78, 6.60
- 50 001: 2.11, 4.55, 2.41, 5.47, 2.07, 6.68, 4.26, 10.55, 2.55, 5.91, 5.29, 13.58, 9.07, 24.64, 3.56, 8.45

**Average Volume (m³):**
- 5 000: 46.29
- 10 000: 44.04
- 20 000: 100.00
- 30 000: 42.97
- 40 000: 40.10
- 50 000: 36.82

**Overhead Costs (TMK/M²):**
- 5 000: 10.12
- 10 000: 1.38
- 20 000: 0.41
- 30 000: 17.54
- 40 000: 2.46
- 50 000: 2.11

**Water VESI (TMK/M²):**
- 5 000: 2.46
- 10 000: 1.94
- 20 000: 2.38
- 30 000: 6.30
- 40 000: 0.94

**Electricity VALATSTUS (TMK/M²):**
- 5 000: 2.46
- 10 000: 1.94
- 20 000: 2.38
- 30 000: 6.30
- 40 000: 0.94

**Cleaning PUNTAANPITO (TMK/M²):**
- 5 000: 2.46
- 10 000: 1.94
- 20 000: 2.38
- 30 000: 6.30
- 40 000: 0.94

**Overhead Costs (TMK/M²):**
- 5 000: 10.12
- 10 000: 1.38
- 20 000: 0.41
- 30 000: 17.54
- 40 000: 2.46
- 50 000: 2.11
### Maintenance Costs and Volume \( m^3 \) per year

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<td>10.24%</td>
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<td>19.95%</td>
<td>8.89%</td>
<td>22.12%</td>
<td>7.56%</td>
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<tr>
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<td>1.28%</td>
<td>3.18%</td>
<td>1.09%</td>
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<td>1.15%</td>
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<tr>
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</table>

<p>| Total cost ( \text{VUOKRA} ) | 43.29% | 99.91% | 42.47% | 99.99% | 39.35% | 99.96% | 41.95% | 99.99% | 40.56% | 100.00% | 43.14% |
| Total cost ( \text{VUOKRA} ) | 3.61% | 7.55% | 100.00% | 3.55% | 100.00% | 3.54% | 100.00% | 3.28% | 100.00% | 3.36% | 100.00% | 3.59% | 100.00% | 3.50% | 100.00% |</p>
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- 1955 - 59
- 1960 - 64
- 1965 - 69
- 1970 - 74

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| TOTAL YHTEENSÄ | 52 | 16 | 12 | 33 | 32 | 34 | 31 | 16 | 12 | 8 | 19 | 265 |

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  - 4
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- **1955 - 59**
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- **1960 - 64**
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- **1965 - 69**
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- **1970 - 74**
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**Total**

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**Tenement Building Companies**
| TENANT - BUILDING COMPANIES | TOTAL VOLUME | 5-000 | 5.001 - 10.000 | 10.001 - 20.000 | 20.001 - 40.000 | 40.001 - 50.000 | 50.001 - | 1 | 14 | 25 | 46 | 43 | 43 | 37 | 26 | 20 | 41 | 332 |
|-----------------------------|--------------|-------|----------------|-----------------|----------------|----------------|----------------|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1                           | 2            | 4     | 1              | 1               | 2              | 1              | 1              | 1 | 15 | 22 | 25 | 46 | 43 | 43 | 37 | 26 | 20 | 41 | 332 |
| 2                           | 4            | 2     | 1              | 1               | 2              | 1              | 1              | 1 | 14 | 25 | 46 | 43 | 43 | 37 | 26 | 20 | 41 | 332 |
| 3                           | 1            | 4     | 1              | 1               | 2              | 1              | 1              | 1 | 14 | 25 | 46 | 43 | 43 | 37 | 26 | 20 | 41 | 332 |
| 4                           | 1            | 4     | 1              | 1               | 2              | 1              | 1              | 1 | 14 | 25 | 46 | 43 | 43 | 37 | 26 | 20 | 41 | 332 |
| 5                           | 1            | 4     | 1              | 1               | 2              | 1              | 1              | 1 | 14 | 25 | 46 | 43 | 43 | 37 | 26 | 20 | 41 | 332 |
| 6                           | 1            | 4     | 1              | 1               | 2              | 1              | 1              | 1 | 14 | 25 | 46 | 43 | 43 | 37 | 26 | 20 | 41 | 332 |
| 7                           | 1            | 4     | 1              | 1               | 2              | 1              | 1              | 1 | 14 | 25 | 46 | 43 | 43 | 37 | 26 | 20 | 41 | 332 |
| 8                           | 1            | 4     | 1              | 1               | 2              | 1              | 1              | 1 | 14 | 25 | 46 | 43 | 43 | 37 | 26 | 20 | 41 | 332 |
| 9                           | 1            | 4     | 1              | 1               | 2              | 1              | 1              | 1 | 14 | 25 | 46 | 43 | 43 | 37 | 26 | 20 | 41 | 332 |
| 10                          | 1            | 4     | 1              | 1               | 2              | 1              | 1              | 1 | 14 | 25 | 46 | 43 | 43 | 37 | 26 | 20 | 41 | 332 |
| 11                          | 1            | 4     | 1              | 1               | 2              | 1              | 1              | 1 | 14 | 25 | 46 | 43 | 43 | 37 | 26 | 20 | 41 | 332 |
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| 13                          | 1            | 4     | 1              | 1               | 2              | 1              | 1              | 1 | 14 | 25 | 46 | 43 | 43 | 37 | 26 | 20 | 41 | 332 |
| 14                          | 1            | 4     | 1              | 1               | 2              | 1              | 1              | 1 | 14 | 25 | 46 | 43 | 43 | 37 | 26 | 20 | 41 | 332 |
| 15                          | 1            | 4     | 1              | 1               | 2              | 1              | 1              | 1 | 14 | 25 | 46 | 43 | 43 | 37 | 26 | 20 | 41 | 332 |
|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Costs | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**Average Costs per Year:**

- 1949: 20.74
- 1950: 16.41
- 1951: 9.17
- 1952: 11.55
- 1953: 14.38
- 1954: 14.38
- 1955: 6.27
- 1956: 19.95
- 1957: 13.86
- 1958: 12.62
- 1959: 7.32
- 1960: 14.49
- 1961: 1.91
- 1962: 5.54
- 1963: 7.88
- 1964: 5.91
- 1965: 6.05
- 1966: 5.39
- 1967: 7.10
- 1968: 5.15
- 1969: 3.69
- 1970: 3.97
- 1971: 3.63
- 1972: 3.45
- 1973: 1.67

**Total Domestic Costs:**

- 1949: 57.09
- 1950: 60.81
- 1951: 19.21
- 1952: 11.94
- 1953: 8.46
- 1954: 5.83
- 1955: 1.99
- 1956: 3.69
- 1957: 6.97
- 1958: 16.62
- 1959: 3.09
- 1960: 5.15
- 1961: 7.10
- 1962: 3.97
- 1963: 3.63
- 1964: 3.45
- 1965: 1.67
- 1966: 3.09
- 1967: 5.83
- 1968: 8.46
- 1969: 11.94
- 1970: 19.21
- 1971: 60.81
- 1972: 57.09
- 1973: 60.81
The original questionnaire includes 14 pages.

Appendix 2. These pages of the questionnaire issued to the maintenance group belong to the set B.
### TILASTOKESKUS – STATISTIKCENTRALEN

Yritystilaasto – Företagsstatistik

**PL 770 00101 Helsinki**

**PB**

10 5.7.1976 aikaan

10 5.7.1976

**Puhelin** - Telefon **90-645121**

**Posta**

10 5.7.1976 aikaan

10 5.7.1976

**Asuntoyhteisön nimi – Jakeluosoite – Postitoimipaikka**

**Bostadssamfundets namn – Utdeelningsadress – Postansätt**

**Mäkiunan Group**

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<tr>
<td>Jakeluosoite</td>
<td>Address</td>
</tr>
<tr>
<td>Utdeelnings-adress</td>
<td></td>
</tr>
<tr>
<td>Postansätt</td>
<td>Post Office</td>
</tr>
<tr>
<td>Puhelin</td>
<td>Phone number</td>
</tr>
</tbody>
</table>

Rahamäärät ilmoitetaan ilman pennimerkintöjä ja pinta-alat ja tilavuudet ilman desimalviejityksiä. Siffrorna i mark uppgas utan pennibeteckningar och arealet och volymen utan decimaler.

### YLEISTIEDOT

#### ALLMÄNNA UPPGIFTER

<table>
<thead>
<tr>
<th>1. Asuntoyhteisön koskukunta</th>
<th>Bostadssamfundets hemkommun</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>2. Asuntoyhteisön perustamisluvuksellisi Bostadssamfundets grundlagningsår</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>3. Täkleuksi Rakennusperiod:</th>
<th>0001</th>
<th>number of buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>0002</td>
<td>number of buildings</td>
<td></td>
</tr>
</tbody>
</table>

4. Juridinen muoto: Juridisk form:

<table>
<thead>
<tr>
<th>1. Asunto-osakeyhtiö Bostadsbolag</th>
<th>Apartment-association company</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Asunto-osuuskunta Av-societät</td>
<td>Cooperative</td>
</tr>
<tr>
<td>3. Kintestbooskeytystä-osoiskunta Fastighetsbolag/andelbolag</td>
<td></td>
</tr>
</tbody>
</table>

| 4. Muu | Annan |

5. Asunnrakennusten lukumäärä: Anial bostadsbyggnader

<table>
<thead>
<tr>
<th>6. Asunnrakennusten luku</th>
<th>Antal bostadsbyggnader</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Muiden rakennusten luku Bostadsbyggnadernas volym</td>
<td></td>
</tr>
<tr>
<td>8. Rakennusten palovakuutusarvo Byggnadernas brandförsäkringsvärde</td>
<td></td>
</tr>
<tr>
<td>9. Huoneestoliä Lägenhetstryck</td>
<td></td>
</tr>
<tr>
<td>10. Maapohjan (tontti) pinta-ala Grundens (kontornas) area</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>001</th>
<th>Building 1 built in</th>
<th>3</th>
<th>3. 4. 5. 6. 7. 8. 9.</th>
</tr>
</thead>
<tbody>
<tr>
<td>002</td>
<td>Building 2 built in</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


12. Maan omistus: Jordbeskrivning:

<table>
<thead>
<tr>
<th>10. Oma maa</th>
<th>Own</th>
</tr>
</thead>
<tbody>
<tr>
<td>20. Vuokramaa</td>
<td>Land-Lease</td>
</tr>
<tr>
<td>21. Kunta</td>
<td>kommun</td>
</tr>
<tr>
<td>22. Mui julkinen sektori</td>
<td>annan offentlig sektor</td>
</tr>
<tr>
<td>23. Mui annan</td>
<td></td>
</tr>
</tbody>
</table>

13. Talotyppi: Husform:

<table>
<thead>
<tr>
<th>1. Kerrostalo</th>
<th>High-rise</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Rivitalo</td>
<td>Vila house</td>
</tr>
<tr>
<td>3. Yhden tai kehden huoneistotalo</td>
<td>other</td>
</tr>
<tr>
<td>4. Hus med en eller två lägenheter</td>
<td></td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>1. Betoni</th>
<th>Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Tegel</td>
<td>Brick</td>
</tr>
</tbody>
</table>

**Tietojen antaminen velvollisuus perustuu lakien (Laki 98/1964, 1 §). Antamanne tiedot idetään palasina (mainitun lain 6 §). Tietojen antamien lainmukaisuus on laissa määritelty rangaistus (mainitun lain 7 §). Skyldigheten tässä on kiinnostavaa, että kirjallinen määrityksestä on tällöin käytössä (Laki 98/1964, 1 §). Tiedottaa, että tietojen antaminen on perusteltua (Laki 98/1964, 1 §).**

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Lähetettä vihdeämitytiedot (Laki 98/1964, 1 §). Tiedottaa, että tietojen antaminen on perusteltua (Laki 98/1964, 1 §).
### 1. Yleistiedot

<table>
<thead>
<tr>
<th>Locality</th>
<th>built in year</th>
<th>3. TLikaus</th>
<th>Rakennuskapp</th>
<th>19</th>
<th>19</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 2. Asuntohyoteen perustamisvuosi

<table>
<thead>
<tr>
<th>Bostadsamfundets grundläggningår</th>
<th>1. Asunnon reaktorinn (komplex)</th>
<th>Bostadsamfundets hemkomplex</th>
<th>2. Asuntohyoteen katsastettu bostadsamfundets grundläggningår</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 4. Juridinen muoto

<table>
<thead>
<tr>
<th>Juridisk form.</th>
<th>Company type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 4.1 Asunto-osakkeenä

- Bostadsaktiebolag
- Cooperative

### 5. Asunnon rekisterin tilavuus

<table>
<thead>
<tr>
<th>Antal bostadshyror</th>
<th>Antal bostadsväsenden</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 6. Asunnon rekisterin tilavuus

<table>
<thead>
<tr>
<th>Antal bostadshyror</th>
<th>Antal bostadsväsenden</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 7. Mooden rekisterin tilavuus

<table>
<thead>
<tr>
<th>Antal bostadshyror</th>
<th>Antal bostadsväsenden</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 8. Rakennusten palovaikutusarvo

<table>
<thead>
<tr>
<th>Antal bostadshyror</th>
<th>Antal bostadsväsenden</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 9. Huoneistoarvo

<table>
<thead>
<tr>
<th>Antal bostadshyror</th>
<th>Antal bostadsväsenden</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 10. Maapoikaisen komplexitas

<table>
<thead>
<tr>
<th>Antal bostadshyror</th>
<th>Antal bostadsväsenden</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 11. Asunnon rekisterin valmistumisvuosi

<table>
<thead>
<tr>
<th>Antal bostadshyror</th>
<th>Antal bostadsväsenden</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 12. Maan omistukset

<table>
<thead>
<tr>
<th>Jordbesittelys</th>
<th>Land ownership</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 13. Taloytypi

<table>
<thead>
<tr>
<th>Hustyp</th>
<th>building type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 14. Rakennustyyppi

<table>
<thead>
<tr>
<th>Hustyp</th>
<th>building type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Puhelin - Telefoon:** 90-645121
**10.5.1976 aikana:** 90-610122

---

**Formularett retuimeras under bilingen synest den:**
**Rahamäärä ilmoitetaan illan pinnemarkkinoja ja pinta-alat ja tilavuudet illan desimaleja.
Sifirorma i mark uppgas utan pinnabeckningar och areal och volym utan decimaler.**

---

**Tiedonantajan nimi:**
**Upplagens namn:**

**Jakeluusoite:**
**Udellnings adress:**

**Postiämtpaikka:**
**Postanstalt:**

**Puhelin:**
**Telefon:**

**Phone number:**

---

**Confidential by law and by-law.**

---

**Ilmoitetaan antamisvillouuksus perustus lakiin (Laki 96/1954, 1 §). Antamanneen tiedot ehdotetaan salaisina (mainitut lain 6 §). Tietojen antamisen mahdollistaa lainsäädäntö (Laki 96/1954, 1 §). Uppgifter Ni gör behandlas konfidentiella (ovan omnämnda laga 6 §). För utrustningats intägare att uppgiffa ädomes straff (ovannämnda laga 7 §).
<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Personnel</td>
<td>Workhours</td>
<td>Labor costs</td>
<td>fringe benefits</td>
</tr>
<tr>
<td>Palgintaajien lukumäärä</td>
<td>Työaikojen lukumäärä</td>
<td>Palkat ja palkkiot</td>
<td>Lönor och arvoden</td>
</tr>
<tr>
<td>Antal lontagare</td>
<td>Antal arbetstimmar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Henrikö Persontar</td>
<td>Tunnla hours</td>
<td>mk</td>
<td>mk</td>
</tr>
<tr>
<td>Person</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Wide day**

1. Kokopäivätoimiset:
   - Iheldagsbefattning:
     - Serviceen och junior
     - 11. Huolto- ja talomiehet
     - Servicenän och gårdskarlar
     - 12. Sivojaat
     - Städare... cleaners
     - 13. Isännötsijät
     - Disponenter managers
     - 14. Muut Övriga... other
     - 060

2. Osapäivätoimiset:
   - Parktime
     - I deltgåsebefattning:
     - Servicenän
     - 21. Huolto- ja talomiehet
     - Servicenän och gårdskarlar
     - 22. Sivojaat
     - Städare... cleaners
     - 23. Isännötsijät
     - Disponenter managers
     - 24. Muut Övriga... other
     - 070

3. Korjausmies
   - Reparatie
     - 078

4. Tilauspalvelu
   - 080

5. Kohdot 1-4 yhteensä TOTAL
   - 088

---

1) Jos tasmällisät tunnusmäärät eivät pysty laskemaan, on ne arvioitava mahdollisimman tarkasti.

Om det exakta antalet timmar inte kan räknas, bör de uppskattas så noggrant som möjligt.

2) Käski palkat ja palkkiot, joista asuntoyhtelöt tärvinantajana on maksanut sosiaaliturvamaksut ja suorittanut annakandutyön lukumääräntöä, kokous-, tilintarkastus- yms. palkkiota. Huolto-, isännötsijän-, bili- tai muuille vastaaville toimistotyö suoritetut maksut eivät merkitä täällä.

Alla lönor och arvoden, för vilka bostadssamfundet i egenskap av arbetsgivare erlagt socialskyddsavgifter och förskottsservice, utom mötesrevisions o.d. arvoden. Till service-, disponent-, bokförings- eller andra motsvarande byråer betalade avgifter uppges inte här.
<table>
<thead>
<tr>
<th>23. Veukrat:</th>
<th>24. Lämmita:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyror:</td>
<td>heating:</td>
</tr>
<tr>
<td>23.1. Tonttivuokrat</td>
<td>energy costs:</td>
</tr>
<tr>
<td>23.2. Muut vuokrakulut</td>
<td>24.1. Polttoainekostot</td>
</tr>
<tr>
<td>23.3. Övriga hyreskostnader</td>
<td>ja muut lämmityskulut</td>
</tr>
</tbody>
</table>
| | Brännsköpp och övriga värme
costs |
| | Avgifter till värme
cologer |

<table>
<thead>
<tr>
<th>25. Vesi:</th>
<th>26. Vaihtautus ja voima:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vatten:</td>
<td>(vain yhteisön osuuus)</td>
</tr>
<tr>
<td>25.1. Käyttöveden kulutusmaksut</td>
<td>Lyse och kraft (bara samfundets andel)</td>
</tr>
<tr>
<td>25.2. Jateveden kulutusmaksut</td>
<td></td>
</tr>
<tr>
<td></td>
<td>bruksvattens förbrukningsavgifter</td>
</tr>
<tr>
<td></td>
<td>Avfallsvattens förbrukningsavgifter</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>27. Puhtaanapito:</th>
<th>28. Vahinkovakutukset:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renhållning:</td>
<td>Skadeförsäkringar:</td>
</tr>
<tr>
<td>27.1. Sivous:</td>
<td></td>
</tr>
<tr>
<td>Ståning:</td>
<td></td>
</tr>
<tr>
<td>27.1.1. Siivousaineet</td>
<td>Insurares</td>
</tr>
<tr>
<td></td>
<td>och -tarvikkeet</td>
</tr>
<tr>
<td></td>
<td>materialet</td>
</tr>
<tr>
<td>27.1.2. Papp åt</td>
<td>Mat ur</td>
</tr>
<tr>
<td></td>
<td>produkt / avvikningsfur</td>
</tr>
<tr>
<td></td>
<td>Avgifter till städningsfirmor och servicebolag</td>
</tr>
<tr>
<td>27.2. Jätehuolto</td>
<td></td>
</tr>
<tr>
<td>Sopiservice</td>
<td></td>
</tr>
<tr>
<td>27.3. Lummivat</td>
<td></td>
</tr>
<tr>
<td>Snörjning</td>
<td></td>
</tr>
<tr>
<td>27.4. Muut puhtaanapitokulut</td>
<td></td>
</tr>
<tr>
<td>Övriga renhållningskostnader</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>29. Korjaukset och huolto:</th>
<th>30. Muut hoitokulut:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reparationer och underhåll:</td>
<td>Övriga underhållskostnader:</td>
</tr>
<tr>
<td>29.1. Käytetty aineet och</td>
<td>30.1. Toimisto- ym. kulut</td>
</tr>
<tr>
<td>tarvikkeet</td>
<td>offerte kosts</td>
</tr>
<tr>
<td></td>
<td>Använda ammen och förmögenhet</td>
</tr>
<tr>
<td></td>
<td>Materiaal</td>
</tr>
<tr>
<td>29.2. Maksut korjaukslikkele</td>
<td>30.2. Maksut kirjanpito-</td>
</tr>
<tr>
<td>ja huoltoyhtiölle</td>
<td>isännötsjämtidmissiole</td>
</tr>
<tr>
<td></td>
<td>Furins</td>
</tr>
<tr>
<td></td>
<td>Avgifter till reparationsfirmor</td>
</tr>
<tr>
<td></td>
<td>och servicebolag</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. KIINTESTÖN HOITKULUT YTEENSA</th>
<th>3. HOITOKATE (= kienteöstön tuotto / kienteöstön hoitokulut)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FASTIGHETENS UNDERHÅLLSKOSTNADER</td>
<td>UNDERHÅLLSTÄCKNING (= fastighetens intäkter / fastighetens underhållskostnader)</td>
</tr>
<tr>
<td>SAMMANLAGT</td>
<td></td>
</tr>
<tr>
<td>4. POISTOT</td>
<td>AVSKRIVNINGAR</td>
</tr>
</tbody>
</table>

1) Esimerkki rutoon. Förteckning rutan.  
2) Aktivitetera korjaukskustannuskälla tarkistatut peruseranneen aiheutuneita kustannuksia, joita ei ole merkitty talousrekisterin tilissä. Updated entries.
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RAOUF, A., and KETTUNEN, O.V., 1976, Developing optimal decision
rules regarding apartment Building Maintenance systems an
application of systems concepts, 3rd European Meeting on
Cybernetics and Systems Research, Vienna, Austria).
RAOUF, A., and KETTUNEN, O.V., 1977, Developing apartment mainte-
nance systems as urban operations, Kybernetes, to be pub-
RAOUF, A., and KETTUNEN, O.V., 1977, Productivity study of apart-
ment buildings maintenance systems. The 4th Interna-
tional Conference on Production Research. Tokyo, Japan.
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1970.
TILASTOKESKUS, 1976, Asunto-osakeyhtiöiden yritystilastotietoja vu-
TURBAN, E., The use of mathematical models in plant maintenance de-
cision making. Management Science, Vol. 13, n:o 6, February,
1967, U.S.A.
COLLECTED UNPUBLISHED MATERIAL concerning the maintenance of apartments from Finland, Sweden, Norway, Denmark, Germany, Netherlands, Soviet Union, Czechoslovakia, United States of America, Canada, Japan, Singapore and Hong Kong. Data is saved and available in the Technical Research Center of Finland, Technical Information Center, Helsinki.

1967
Completed secondary education at Lyceé of Oulu, Finland.

1968
Was promoted Second Lieutenant in the Army of Finland on September 5th. Officer in the reserve.

1970
Earned a Diplom-Ingenieur degree in Civil Engineering from the University of Oulu, Finland.

1973
Worked as Research Engineer at the University of Oulu, Laboratory of Building Economy, Finland.

1974
Worked as Research Assistant at the Academy of Finland, Helsinki and Oulu, Finland.

1974
Joined the Technical Research Center of Finland. Worked as a Senior Research Engineer for the Building Laboratory, Oulu, Finland.

1975
Earned a Licentiate of Technology degree from the University of Oulu, Finland.

1975
Joined the University of Western Ontario for graduate studies in Industrial Engineering, London, Ontario, Canada.

1977
Industrial Attaché of Finland at the Embassy of Finland, Washington, D.C., U.S.A.
VITA AUCTORIS

Osmo Vilho (Ville) Kettunen:

1947 Born in Oulu, Finland, on March 2nd.

1967 Completed secondary education at Lycée of Oulu, Finland.

1968 Was promoted Second Lieutenant in the Army of Finland on September 8th. Officer in the reserve.

1973 Earned a Diplom-Ingenieur degree in Civil Engineering from the University of Oulu, Finland.

1973 Worked as Research Engineer at the University of Oulu, Laboratory of Building Economy, Finland.

1974 Worked as Research Assistant at the Academy of Finland, Helsinki and Oulu, Finland.

1974 Joined the Technical Research Center of Finland. Works as a Senior Research Engineer for the Building Laboratory, Oulu, Finland.

1975 Earned a Licentiate of Technology degree from the University of Oulu, Finland.

1975 Joined the University of Windsor for graduate studies in Industrial Engineering. Windsor, Ontario, Canada.

1977 Industrial Attache of Finland at the Embassy of Finland, Washington, D.C., U.S.A.
179021

Born in Gun, Finland, on March 9th.

1943

Completed secondary education at Lycee of Gun, Finland.

1945

We were promoted Second Lieutenant in the Army of Finland.

On September 5th, Officer in the Reserve.

1946

Earning a Diploma-Ingnier Degree in Civil Engineering from the University of Gun, Finland.

1947

Worked as Research Engineer at the University of Gun.

1948

Worked as Research Assistant at the Academy of Gun.

1949

Heininki and Gun, Finland.

1950

Joined the Technical Research Center of Finland. Worked as a Senior Research Engineer for the Building Laboratory.

1952

Earning a Licentiate of Technological Degree from the University of Gun, Finland.

1953

Joined the University of Windsor, Ontario, Canada.

1954

Graduated from the University of Windsor as the Master of Engineering.

1955

Worked in Washington, D.C., U.S.A.