

# Maintenance in Real Estate and Manufacturing Industries: Differences, Problems, Needs and Potentials - Four Case Studies

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**Abstract** It is about 50 % of the activities in the housing sector in the EU region are related to maintenance. According to several publications, building management systems are still quite rare and efficient methodologies for service life prediction of building parts still need to be developed. Also, recent studies show difficulties in finding comprehensive answers concerning, e.g. identifying risks and preventive maintenance actions. Incomplete information can easily lead to incorrect maintenance actions. The problem addressed is: How to improve performance and cost-effectiveness of the maintenance applied on real estate facilities especially buildings to reduce maintenance and management costs and increase company profit? The study's objectives are to analyse maintenance; techniques, costs, weaknesses and potentials, and compare it with manufacturing industry experience. Also, to investigate whether there is a need for a DSS for planning and follow up cost-effective CBM. The major results of four case studies are; (1) Preventive and breakdown maintenance are mainly used and actions are funded from different accounts. (2) The concept of cost-effectiveness is applied occasionally. (3) Lack of CBM-DSS for planning, follow up and evaluate maintenance profitability, and cost-effective improvements of company business and tenant living quality. (4) The profit generated by continuous heating of building thanks efficient maintenance is about 2.332 million SEK. The major conclusion; there is a reasonable opportunity to reduce buildings' management and maintenance costs.

**Keywords** Maintenance techniques in real estate facilities • Cost-effectiveness • Comparison between maintenance in manufacturing and real estate industries • CBM • Decision support system

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## 1 Introduction

It is reported that about 50 % of the activities in the housing sector in the EU region are related to maintenance, and slightly lower for the “non” housing sector (Silva et al. 2009). From everyday experience, some of the economic losses that occur in real estate arise out of acute problems or unnecessary replacements of building components, such as refrigerators, roofs, windows, doors. To reduce these losses, maintenance actions may be planned for a building component based on its state instead of calendar time or age. But, these actions cannot effectively be accomplished if the strategy of condition-based maintenance (CBM) is not implemented. In general, by applying proper CBM, it is possible to utilise larger part of a component life cost-effectively without increasing the risk of urgent problems. Research results emphasis that the return on investment in CBM in manufacturing industry is 5–10 times the invested capital (Al-Najjar 2007). Implementing CBM provides; effective data management, proper measurements analysis, planning and executing actions cost-effectively in convenient times (Al-Najjar 2012). Therefore, a profitable maintenance is that which; ensures a right action is done at right component/equipment, right time, in a right way and at a right cost which is less than the losses triggered that action. That there is a strong link between maintenance on one hand and company profitability and competitiveness on the other hand has been shown by many authors (Pulselli et al. 2006; Al-Najjar 2007, 2009; Kans 2008; Ingwald 2009). About 30–40 % of all natural resources utilised in industrialised countries are used in the real estate/construction industry (Pulselli et al. 2006). It is thus highly relevant to introduce CBM strategy to the real estate industry. Facilities Management is a source management that combines people, property and management expertise to provide vital services in support of the organisation (Nik-Mat et al. 2011; Chen et al. 2013). It is also emphasised that the aim of Facilities Management should not be limited to simply reducing the operating expenses of a built facility, but it should focus on enhancing efficiency of the facility as well. According to Garrido et al. (2012), building management systems are still quite rare, and efficient methodologies for service life prediction of building materials still need to be developed. Also, according to Bhavnani (2005), recent studies show difficulties in finding comprehensive answers for how to identify risks and preventive actions, because incomplete information can easily lead to incorrect maintenance operations. Therefore, the problem addressed is: How to improve performance and cost-effectiveness of the maintenance applied on real estate facilities especially buildings to reduce maintenance and management costs and increase company profit? The main objectives of the study are to:

1. Map, identify and analyse maintenance techniques, weaknesses and potentials.
2. Investigate maintenance costs in specific companies within the real estate industry.
3. Compare maintenance experience from real estate industry and that from manufacturing industry.

4. Investigate if there is a need for a decision support system (DSS) for facilitating the implementation of cost-effective CBM and follow up its performance from technical and economic perspectives.

For reviewing the past research, a survey in ScienceDirect showed no hits when we searched for how maintenance is planned and funded in real estate companies; which maintenance strategies were used; and how to achieve cost-effective CBM in building. Also, the search gave zero result when we searched for CMB system or intelligent CBM system for real estate facilities.

## **2 Phases of the Study and Description of Case Companies**

In this study, we use the system theory approach. It aims to specify possible courses of actions together with their risks, costs and benefits. This is why we consider a building as a system that can be divided into different subsystems and components, such as cooling system, pumps and roof. The management system can also be divided into subsystems, such as maintenance, administration, IT and economic. The partition of a building in this manner facilitates the data gathering and analysis to identifying and localising problems, and interactions between sub-systems, e.g. pump performance, maintenance processes and funding. It also facilitates identification of similarities/differences between companies, and estimation of the transactions between sub-systems. The study was planned in the following phases; mapping maintenance activities; identifying existing maintenance techniques, i.e. strategies, policies, methodologies and philosophies; and analysing of maintenance; weaknesses, potentials in four companies within real estate in the City of Växjö, Sweden. We also investigate the need for more advance technologies, e.g. CBM, to provide more cost-effective maintenance. Maintenance in the case companies is analysed to, among others, investigate and consequently judge whether there is a need for an intelligent CBM-DSS to achieve: (1) Better use of resources. (2) Fewer urgent maintenance actions, e.g. repair. (3) Lower maintenance costs. (4) Greater involvement of buildings' users in maintenance. (5) Greater satisfaction for the tenants. In order to achieve the objectives of the study, we analysed companies' activities in maintaining buildings' quality to identify, describe and classify the maintenance techniques applied. It is done with attention is given to maintenance planning, execution and follow up. The study is conducted through: (1) Identifying a person of relevant authority and experience, e.g. maintenance chef, from every company to represent his/her company in the project. (2) Data gathering from personnel (interviews according to 1 above) and maintenance systems. (3) Data analysis with respect to maintenance performance, maintenance cost-effectiveness and experience, opportunities for applying CBM and the need for advanced DSS. (4) Reporting of analysis results and recommendations. (5) Seminars to discuss the methodology and results, and to disseminate knowledge and experience. (6) A workshop to describe and estimate the economic role of maintenance in company

business. Exploratory principal objectives for this study are to identify, map and analyse current maintenance techniques and their performance in four real estate companies that owning about 65 % of the rental buildings in the City of Växjö. These companies are: (1) Hyresbostäder and Växjöhem own about 240,000 and 460,000 m<sup>2</sup> resp., mainly residential buildings and partly buildings for geriatric care. (2) Videum owns about 115,000 m<sup>2</sup> housing area and about 80,000 m<sup>2</sup> is devoted for Linnaeus University (offices, classes, laboratories, libraries). (3) VöFAB owns about 270,000 m<sup>2</sup> mainly is business area on Växjö communal buildings.

### 3 Data Gathering

In order to achieve the exploratory objectives, an interview template including the following questions was developed to be answered by the case companies:

1. How maintenance is defined? What maintenance strategies have been used? Maintenance needs, planning, budget, performance, follow up and improvements?
2. What are the resources, e.g. skills, materials, time, required for doing maintenance actions? If these resources are not available, how long is the waiting time?
3. What are the problems that handled by maintenance and can be classified as; general, regular and rare but costly problems?
4. What are the reasons behind these problems; management, construction, use, others?
5. What are the maintenance actions that the company take for various reasons and why?
6. What are the costs that usually considered in maintenance budget?
7. How much does maintenance cost annually for the past 3–5 years?
8. Are the maintenance economic data accessible for analysis?
9. Does/how a company plan to use/already use, the concept of cost-effective maintenance? If not, why?
10. Does/how the existing systems fit for planning, follow up and improvement of maintenance? Otherwise, what is missing? Does the company need a DSS to facilitate applying cost-effectiveness CBM?

Four interview sessions were conducted with a person from each of the case companies. The interviewed persons were responsible of maintenance (and/or management) of buildings in respective case company. They possess sound knowledge, experience and understanding of maintenance. The interviews were conducted by two persons and recorded to ensure the correctness and quality of the information that were gathered during the interviews.

## 4 Data Analysis

The information gathered from the case companies was analysed considering the similarity and differences between companies (and also the differences between the case companies and manufacturing industry) in planning, budgeting, execution, follow up and improving maintenance performance. The analysis consider also experience and knowledge that are important in the establishing and running cost-effective maintenance.

### 4.1 *Comparison Between Case Companies*

The case companies have some of maintenance features in common, and the differences are:

- Case companies fund maintenance activities differently from preventive maintenance (PM), operation/management, repair, damage to property or/and land management accounts. PM and operation accounts were mostly used.
- Maintenance actions are executed using either company own personnel, external resources or both.
- The data used for planning maintenance actions; in Videum, measurements from technical equipment were used. The rest of the case companies use previous experience.
- The major problems that maintenance handle were also different. Design problems were usual at Hyresbostäder. But, the most usual problems at Videum were technical equipment problems, e.g. pumps, compressors, sensors, temperature, fans.
- The causes behind these problems were also dissimilar. At Hyresbostäder, construction problems were obvious, but at Videum the equipment deterioration was the major cause, aging was behind the problems at VöFAB.
- Total annual maintenance cost and maintenance cost per m<sup>2</sup> were also different. The cost of maintenance per m<sup>2</sup> varied between; 130–273 SEK/m<sup>2</sup> and the total annual maintenance cost varied between 6.5 and 91 million SEK.

### 4.2 *Maintenance Strategies in Manufacturing and Real Estate Industries*

IT applications have proven effective in the maintenance of constructed facilities (Ko 2009; Shen et al. 2010). Duarte et al. (2013) claims that maintenance activities represent an increasingly high cost in any manufacturing system or in different types of structures. Also, in order to reduce production cost, minimise downtime

and ensure reliability levels, DSSs should be able to optimise maintenance plans and ensuring companies meeting their strategic goals. In the real estate industry, a building is usually partitioned into a number of components/parts, and maintenance work is scheduled for these components in different time ranges.

The case companies define maintenance: the activities needed to maintain building quality. They use preferably:

- (a) PM; the maintenance actions planned and budgeted annually to reduce the likelihood of emergencies.
- (b) The rest of the activities, i.e. activities that cannot be predicted and planned in advance, e.g. repairs and replacements associated with emergencies/failures or based on fault/inspection reporting.

The expenses of the rest of the activities is directly influenced by PM budget and quality. Although PM reduces the risk of emergencies and accidents, but it typically leads to two losses due to: acute problems (breakdowns) than happen before maintenance actions are done, or loss of a part of the life of the component when it is replaced before its useful life has been exhausted (Al-Najjar 2012). Consequently, economic losses are generated because of costly failures and unnecessary early replacements of building components. But, according to Al-Najjar (1997), maintenance activities in industry are conducted with regard taken to different strategies:

- At failure by restoring the machine to the same as before (Breakdown maintenance).
- Using models for regular planning of maintenance actions regardless of real needs and previous events.
- Based on the machine state, i.e. do nothing until it is really needed. Such maintenance action is done to avoid disruption when symptoms reflecting deterioration type and its severity are measurable.

In the first two strategies there is a clear similarity between maintenance experience from real estate and manufacturing industries. But, the third differs appreciably. In this paper, we define cost-effective maintenance actions as the actions that result in less acute problems, prolonged component life cycle and shortening repair time, i.e. reducing owning and operating costs more than what maintenance actions cost. It is always important to select the most cost-effective maintenance (Ingwald and Al-Najjar 2012). The selection depends on some parameters. In real estate industry these parameters can be; building component type and its state, cost and benefits of maintenance actions, energy consumption, personnel competence, housing satisfaction and age. To make this selection properly, it demands relevant and high quality technical and economic data (Ibid).

### ***4.3 Maintenance Budgeting, Execution and Follow up in Manufacturing and Real Estate Industries***

In manufacturing industry, using CBM, it becomes easier to identify damage in the monitored equipment, assess its severity and identify-prioritise the components that must be addressed for maintenance. Therefore, it is possible to plan actions effectively so that the equipment/components that suffer from wear and tear can be replaced or repaired in right time, e.g. at a planned downtime (Al-Najjar 2000). From everyday experience, the determination of time until a maintenance action can be done using analysis system, individual experience or just subjectively, i.e. based on instinctive/emotional feelings. In this study, we consider the factors of high importance in selecting the more profitable maintenance time to be: (1) The size of the capital tied up in equipment. (2) Existing state of the equipment and the causes behind deterioration. (3) Rate of deterioration of the equipment. (4) Probability of failure of the machine given a particular damage under development. (5) Statistical remaining lifetime when this damage is under progress. (6) Failure consequences. To continuously enhance company profitability, the main objective of conducting efficient maintenance should be to enhance maintenance cost-effectiveness. Feedback from maintenance applications helps to prevent recurrence of the same or similar problems, which in turn improves the cost-effectiveness of maintenance and its results and reduces maintenance direct cost (Ingwald and Al-Najjar 2012). Maintenance direct cost can, in general, be divided into: (1) Man-hours for the repair/replacement of units. (2) Physical inspection. (3) Consuming material, tools, equipment, etc. (4) Outsourcing of maintenance. (5) Overhead costs, such as equipment, offices, management, etc. (6) Invested capital in training, new analysis software program or system (Al-Najjar 2007).

In the case companies, maintenance budget is planned by prioritising maintenance actions for the greatest benefit especially when it concerns reducing energy consumption, because it can be measured and followed up. In most cases the companies use their own personnel to repair building components, such as water pipes, building facade or component colour. Maintenance personnel also serve as a source of information when they report every fault they notice during their visits to companies properties. At two of the four case companies, maintenance activities' costs are shared between PM budget and operation/management. In one company, maintenance activities' costs are shared between PM budget, operation/management and repair, and in the fourth company maintenance activities' costs are shared between five accounts: (1) PM-budget; funding the annually planned maintenance activities. (2) Operating/management budget is to fund the activities that cannot be predict, e.g. repair of urgent problems. (3) Repair account; in certain companies repair account is separated from the other activities that are explained above. (4) Damage account; it is for funding all injuries occurring on the buildings. (5) Land-care account; it is for funding the expenses required for land management. While in manufacturing industry all machines maintenance is funded from one maintenance budget. External services that bought by companies are quality checked

using special standard. The quality of smaller maintenance projects within the company are controlled by the project manager. Staff experience and knowledge are used for follow up maintenance project activities and improving maintenance performance. But, the case companies lack of a system for systematic and documented project execution, control and follow-up that is required for achieving profitable and continuously improved maintenance performance, quality control and quality assurance of maintenance work, detect anomalies and prevent repetitive problems.

#### ***4.4 Maintenance Cost-Effectiveness***

In general, companies strive to reduce costs without compromising on quality and safety. In this study, a maintenance investment is considered cost-effective if it generates savings in production costs larger than the invested capital, i.e. increases the value added. This can be achieved by reducing unplanned downtimes through identifying and eliminating causes behind downtimes which converts maintenance from a cost- to a profit-centre (Al-Najjar 2007). This is could not be visualised by using available accountancy systems and software program because they cannot describe and assess more than maintenance costs, such as maintenance saving, results, losses. The major reason; maintenance in the available accountancy systems is considered cost and only cost. In many cases, when several quotations for the same maintenance project are applied, a quotation is selected based on; (1) Personnel experience. (2) Amount of energy savings when it is possible to estimate the savings. (3) Personnel instinctive/emotional feelings at lack of experience, or (4) Quotation cost, i.e. looking for the cheapest. But, a quotation demands more investment does not need to be poor option, and not the one that costs less investment is the best option. Cost-effectiveness of an investment should be estimated (considering the factors that affect or are affected by the investment) on the long term, i.e. over the entire amortisation period. Therefore, it is possible that the alternative quotation costs higher investment can be the most profitable maintenance investment. In the case companies, there was no document describing what cost-effectiveness means when it comes to maintenance projects. But, the practice is not lacking and maintenance personnel try to do as much as possible within the budget framework. Also, cost-effectiveness is used as a guideline for selecting what they call a good! quotation. But, lack of tools and systems required for easy, certain and effective application and follow up made the cost-effectiveness concept is occasionally used, e.g. in the projects when it is possible to increase the benefits through pressing down project costs. Another example, if a company gets two quotations for one maintenance/operation project but of different costs and lead to different operation/management costs, the company chooses the quotation that saves more costs. Also, the case companies select the equipment of larger tied up capital if it yields less energy consumption justifying the increment in the purchasing cost. Observe! no one knows if it was really economically worthwhile selection or not, because it usually cannot be followed up to examine the claim of



cost-effectiveness. But, is it really possible to know with high certainty whether what is planned or performed is cost-effective without using a reliable model, effective tool or system for this purpose? The answer is most likely NO (Al-Najjar et al. 2004). The case companies did not follow up a project and assess whether it was cost-effective or not due to the lack of such functions in the currently available systems. However, some companies follow up energy savings. Also, in some of the investigated companies, the concept cost-effectiveness is applied through: (a) Identify how the problem has been initiated and how to prevent its recurrence. (b) Make sure that the solution does not create changes in the structure, and (c) The project cost is justified by the results quality. This approach represents a way to reduce maintenance cost as claimed by the case company. Applying this approach, it is assumed that the identification and elimination of the causes behind high cost are successfully done, and the result justifies the costs incurred in conducting maintenance tasks.

It would appear from both quantitative and qualitative data that the case study company may not be adhering to a systematic approach to making decisions to replace circuit breakers and isolators. The lack of corroboration between historical data and respondent narratives suggest that replacement decisions were not consistent between 1999 and 2013. It is puzzling as to why detailed assessments were not carried to establish the condition of the substations. Instead, the historical data and responses strongly suggest that the decisions to replace switchgear were made on ad hoc basis. This brief paper illustrates the suboptimal nature of equipment replacement decisions, and how this can be exacerbated by inconsistent data and information.

Maintenance work in the case companies lacks of a systematic way to pre-evaluate quotations for the same maintenance task/project, and compare them to choose the most profitable maintenance investment. According to their experience, what is missing is a system for planning, budgeting, execution and follow up cost-effective maintenance, and estimating maintenance economic impact. Currently, the follow-up and evaluation of maintenance investment cost-effectiveness is based entirely on personal experience. It is done through comparing a new project with previous one in a subjective way. But, when these people are retired or moved to another companies, it will be almost impossible to carry out even such subjective follow up and evaluation.

#### ***4.5 Example: Cost-Effectiveness of Energy Pumps Maintenance***

In the case companies, there was no specific information describing the economic impact of the maintenance of energy pumps although the heating system is running almost continuously without problems with highest load during autumn and winter. In this section, we assess maintenance economic importance for energy pumping responsible of distributing heat to buildings. Hyresbostäder is select due to the

easiness of data gathering concerning maintenance of energy pumps. The company has 51 energy pumps of type Wilo, Stratos D40. In this example, we did not give attention to the relationships between the heat providing company (VEAB) and the case company purchasing heat for their tenants. Also, we have excluded the impact of discontinuity of building heating. This is because these issues were irrelevant for the case company and outside the context of this paper. In order to estimate the economic benefit of maintenance work on energy pumps, we need to know: average costs, revenue and profits per property, and maintenance and heating expenses at least for 2012. We aware of it can be a rough estimation if we consider the average costs and revenue per property, because properties surface areas varies between 1000 m<sup>2</sup> to over 20,000 m<sup>2</sup>. But as long as there is no more data available, it however, will give an indication of the economic importance of maintaining energy pumps, and to motivate companies to gather more relevant data in future. In Hyresbostäder:

1. The rental housing were 41 buildings at the end of 2012.
  - Heating cost of all buildings during year 2012 was in total 23.6 million SEK. Average revenue per building was 6.402 million SEK, and from all 41 buildings was 262.482 million SEK, where the heating cost is approximately 9 % of the revenue.
  - Average profit per building in 2012 was 0.455 million SEK as the year results (excluding property sales). The total profit for 41 building was 18.655 million SEK.
  - Operating, maintenance and management cost in 2012 was on average 4.593 million per building. This includes costs of building management, repairs, heating, administration, maintenance, taxes and depreciation. But due to the lack of information, it does not include the central administration costs and interest rates that also can be significant costs. The total cost of 41 buildings was 188.313 million SEK.
2. The economic importance of maintaining the heating system is estimated in the following manner:
  - (a) Divide the total heating cost (23.6 million SEK) to the operating/management cost in 2012 (188.313 million SEK) yields 12.5 %.
  - (b) If we multiply 12.5 % with the revenue in 2012, we get the revenue generated by providing heat equal to 32.81 million SEK. It means 1 h unplanned stoppage of the heating system costs about 3745 SEK losses in revenue. A failure of the heating system may cost the company between 22,470 and 134,820 SEK based on which time in the year (winter or summer), because in winter it takes longer time. The losses per 1 h stoppage of one pump can then be 441-2643 SEK, depending on the failure and timing.
  - (c) Total salary cost of maintenance personnel responsible of the stations of energy pumps is 0.475 million SEK per year 2012. Heating profit becomes then: 32.81 (revenue) – 23.6 (heating cost) – 0.475 (maintenance) = 8.7 million SEK (1)

Note that spare parts costs, central administration, interest rates and overhead costs are not included.

- (d) We can assess heating profit alternatively through; the average profit per building in 2012 is 0.455 million SEK (for 41 building, it is then 18.655 million SEK). It means (roughly) that the profit due to heating is:  $0.125 * 18.655 = 2.332$  million SEK (2)
- (e) The difference between the two assessed heating profits in Eqs. (1) and (2) is probably due to the difference in the cost factors shown in (c) and (d), respectively. In (c) some expenses are excluded where are they included in (d). Unfortunately, it was not possible to exactly assess the missing expenses.

The number of energy pumps failures during 2012 was negligibly small, and avoiding these failures keeps heating process running without disturbances and economic losses. Therefore, the profit generated due to a continuous building heating is in the first hand a merit of maintenance staff because they had maintained the heating process running without failures.

#### **4.6 CBM and DSS to Plan, Execute and Follow up Maintenance Cost-Effectively**

Chew and De Silva (2003), argue that early feedback on poor building maintenance and construction could prevent recurrence of problems. According to Motawa and Almarshad (2013), decisions for building maintenance require various types of information and knowledge created by different members of construction teams, e.g. maintenance records, work orders, causes and failure consequences. To assess reliability of a part in a building, the distribution function for the expected time to failure, mean time to repair and decision time should be properly studied according to Myrefelt (2004). It demands the same requirements even if we assessing the reliability of a component in a producing machine. But, the major problems facing this assessment is the availability of high quality failure data which are not easy to find, and also possibility of making realistic assumptions at modelling. In many cases, these two difficulties reduce the certainty in the model appreciably (Al-Najjar 2012). To reduce economic losses, maintenance activities can be planned based on the condition of each component in the building, i.e. using proper and well accommodated CBM for building components. This means that the maintenance will be done only when a real need exists, and not according to a fixed schedule (British standard BS 3811:1993). Application results of CBM would lead to better use of resources, smaller number of emergency actions, lower maintenance costs, greater involvement of building utilizers in maintenance strategy and greater comfort for the residents, and consequently more profit is generated (Al-Najjar 2007). It possible to find publications introduce systems for integrating different activities related to maintenance of buildings, but the major focus of these systems is on integrating databases, data gathering and performance measure assessment

(Ko 2009). In Shen et al. (2010), the authors present an agent-based, service-oriented approach for integrating data, information and knowledge during the entire facility lifecycle. The same thing can be said about (Nik-Mat et al. 2011), the authors focus on functional, technical and image aspects of maintenance. In the case companies, the concept cost-effectiveness is occasionally applied because it is not easy and manageable to apply if there is no system helps in planning, execution and follow up cost-effectiveness of maintenance projects. Such system can also be used for more efficient execution of cost-effective and continuous improvement of maintenance performance. The improvement is now done based entirely on personal learning process. Therefore, case companies demand is an efficient system that combines personal experience and intelligent CBM-DSS for applying concept cost-effectiveness continuously. The experience of maintenance personnel is great and extensive, but it is not documented. Development of such experience is costly for the companies and has taken many years to build up. In order to keep this experience in house, it demands a reliable knowledge-base for preserving the available experience and make it accessible for all personnel. Maintenance costs represent a large sum of budget in the case companies. The sum varies among companies between about 7 and 91 million SEK annually. But at the same time, big maintenance budget may also mean an additional source to increase the company revenue. The latter can be achieved through applying a cost-effective maintenance that reduces maintenance and operating/management costs, and an intelligent system for planning, follow up and evaluating maintenance activities and its contribution in a company profit (Holmberg et al. 2009). But, a successful application of this idea is necessary to confirm this hypothesis in real estate industry.

## 5 Results, Conclusions and Discussions

Based on the data gathered from the case companies, the analysis results are summarised as:

- (a) Maintenance is well defined in all the case companies but not documented.
- (b) PM is mainly implemented to reduce the number of acute problems and repairs.
- (c) Repairs of the acute problems are prioritised based on their consequences and benefits.
- (d) Maintenance activities are funded from two to five different accounts (PM budget, operation/management, repair, damage/vandalism and land management).
- (e) The funding way of maintenance makes benchmarking of maintenance in the case companies impossible.
- (f) Maintenance work is carried out with the help of internal and external resources.
- (g) Maintenance personnel have good and extensive experience but it is not documented.

- (h) Cost-effectiveness concept is not documented and it is only used occasionally and in certain projects.
- (i) There is lack of a system required to detect anomalies, prevent repetitive problems, control and assure quality of maintenance projects, cost-effective and continuous improvement of maintenance performance.
- (j) The profit generated by non-stop heating of building thanks efficient maintenance is in minimum about 2.332 million SEK.
- (k) There is a reasonable opportunity to reduce buildings' management and maintenance costs.

The planning and execution of maintenance in the real estate industry is somewhat different compared with the industrial view on maintenance, but the basic needs are the same. The main notable differences are the way of funding maintenance actions and the level of technology application. While industry today, apply advanced CM technology and DSSs, which are not utilised by the case companies. This, among others, results in experiences and knowledge not being documented, and decision making with low support from information technology.

It is obvious that carrying on maintenance in the way described in the case companies will make it very difficult to know whether maintenance performance was cost-effective or not. Thus, studies to re-arrange maintenance funding accounts, re-define and determine clearly maintenance activities are demanded. These studies are important to ease the follow up of maintenance effectiveness and assess its costs, savings and results. Experience from manufacturing industry is advantageous to utilise for improving maintenance in real estate companies. Implementing a cost-effective maintenance and intelligent systems for planning, follow up, evaluation of maintenance performance and estimation of maintenance financial contributions provides a real opportunity for real estate companies to reduce costs and gain more revenue. Maintenance performance, tools for follow up and evaluation of maintenance should continuously be enhanced with respect to job quality, cost minimisation and delivery accuracy. This is a necessity in order to continuously improve maintenance profitability and increase company profit. Also, it will motivate maintenance staff to demonstrate the usefulness of their maintenance work especially economically. The profit generated by continuous heating of building thanks efficient maintenance is in minimum about 2.332 million SEK. Therefore, there is a reasonable opportunity to reduce buildings' management and maintenance costs. CBM may not be suitable for all building components from the first moment of application, because it is not possible to confirm availability of the technologies required for such CM. Therefore, a special study to investigate available techniques, develop new techniques and implement CM tools and systems to monitor the condition of specific components will be the next step. Applying accommodated CBM-DSS for buildings, it may be possible to overcome the constraints detected in planning, and executing profitable maintenance.

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