Waste in construction projects

call for a new approach

Per-Erik Josephson och Lasse Saukkoriipi

The Centre for Management of the Built Environment
Building Economics and Management
CHALMERS UNIVERSITY OF TECHNOLOGY
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Preface

This report deals with waste in building projects, that is, parts of the job and work tasks that are done without there being any actual value in them for the customer. The concept of waste was chosen for two reasons – one, because it is the term that is used internationally and, second, to make it clear that we in fact waste a great deal of effort on carrying out work that is not useful to the organisation that is paying for it or, in other words, the customer.

The purpose of the report is to offer facts that stimulate and give greater depth to the sometimes confusing debate on building costs. The report has a broad target audience: politicians, branch representatives, heads of companies, line managers and specialists in nearly all groups of actors. Each of these can actively contribute to reducing waste and thus help both to increase profits and reduce the price to the customer.

We want to direct warm thanks to all the organisations, networks and individuals that we have worked together with in the study that has produced this report.

Research and Development West (FoU-Väst), organised within The Swedish Construction Federation, which initiated the study and gave support in its planning and conduct.

The Development Fund of the Swedish Construction Industry (SBUF), which considered the study to be valuable and financed the greater part of the work.

The Centre for Management of the Built Environment (CMB), a cooperative effort between Chalmers University of Technology and the construction and property sector, which both took part in the study and gave partial financing for it.

The Forum for Building Costs at The National Board of Housing, Building and Planning, whose purpose is to create better and cheaper homes and who showed great interest in the study and gave partial funding (registration number 504-1591/2004).

Competitive Building, a national Swedish research school with which the study is associated.

Cooperating companies, most importantly FO Peterson & Söner, Fristad Bygg, JM and NCC, who actively took part in several of the sub-studies and in several creative discussions about what is and what is not waste. Bostadsbolaget and Peab have taken an active part in individual sub-studies.

All the individuals, including representatives of companies and representatives of future building owners, construction managers, architects, design engineers, installation consultants, building contractors, installation contractors and materials suppliers that have participated in the brainstorming meetings, group discussions, individual interviews and conversations and in other means of data collection.

Thanks also to Liz-Marie, Anton, Mattias, Emma, Mikael, David, Edward, Katarina, Henrik and Klas, who have helped us with the data collection.

Göteborg, September 2005

Per-Erik Josephson Lasse Saukkoriipi

Preface for the English version

The report has received such attention within Swedish construction sector that we were recommended to produce an English version. This version is a translation of the original report. We have only made some minor changes and updates. Note that all examples presented are from construction projects in Sweden or from other sources concerning Sweden and its systems and cultures. However, the main message is still relevant for most organisations irrespective which country and culture it has its businesses in.

We argue in this report that the costs for construction could be reduced by 30-35% through reducing waste in most processes and for most products. We also argue that much improvement initiatives tend to increase waste instead of solving problems. However, we should have in mind that there are lots of initiatives, which actually decrease waste. We find these examples in how individuals plan their working days, in how groups organize their work, in how firms find new business solutions, in how customer-supplier relations really give smarter solutions, and in how the government make companies life more simple.

Göteborg, December 2007

Per-Erik Josephson Lasse Saukkoriipi

Summary

This report describes the results of an inventory of waste in building projects. The purpose is to stimulate the ongoing and sometimes confusing debate on building costs by giving examples of things that are done unnecessarily, that is, activities that are not of any value to the customer. In initial brainstorming seminars, 750 activities or documents were identified that were considered to be without value. Inventories of waste were made in a number of priority areas. Direct observations were mixed with individual interviews, group discussions and studies of project documentation.

The inventories show that waste reaches some 30-35% of a project's production cost, i.e. of what the customer pays. The greatest portion of this is hidden to the actors in the sector, primarily because of poor insight into what activities provide value to the customer and what activities do not. The report gives examples of waste divided among four main groups.

- *Defects and checks.* The costs of visible and hidden defects are great. Costs for checks, inspections, insurance, theft and destruction of property are also high. Waste in this group accounts for more than 10% of a project's production cost.
- *Use of resources.* The inventories showed a surprisingly large proportion of waste in the form of wait time, machinery not in use and material waste. This waste corresponds to more than 10% of a project's production cost.
- *Health and safety.* Waste associated with work-related injuries and illnesses is so large that it is reported as a separate group. The greatest portion of the cost is for rehabilitation and early retirement and indirectly adds extra cost to projects via taxes. Waste in this group represents more than 10% of a project's production cost.
- *Systems and structures.* The examples of waste discussed in the report, such as long land use planning processes, extensive purchasing processes and a great deal of documentation, together correspond to approximately 5% of a project's production cost, although this group is the one that is most underestimated in the inventory. There is a tendency that improvement work leads to cumbersome management systems.

The inventory does not report all waste that is a cost to the customer. The definition of waste is applied carefully. Against that background, we suggest that the building sector adopt a common vision of halving production costs in the long term. We find further support for that suggestion in several of our inventories, where we see that the work done to increase value is considerably less than half of the work that is carried out.

Four obstacles to development are discussed: the idea that building is unique and conservative, poor insight into what is value-increasing work, the paradox that improvement work in fact leads to greater waste and that the structure of the building sector works against development.

Reducing waste is one of the greatest challenges, and should be one of the highest priorities, for both individual companies and the building sector as a whole. The first step in this development is to create broad insight into – and an ability to judge – what activities increase value and what activities are actually waste. This can be achieved in several ways, such as by broad education of all workers, including suppliers' employees, and a strong focus on the main process in projects. The report also proposes a focus on manufacture, since the greatest part of the resources are used there, and on

federal authorities taking the opportunity to set examples by openly reporting how they eliminate waste.

It is further recommended that further inventories be made to gain even greater knowledge of the size of different types of waste and what they consist of, as well as to gather more examples in order to push the debate and development work forward.

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INTRODUCTION

1 Why should we study waste?

Production costs are too high – or are they?

There has been an intensive debate for a number of years about costs for construction in Sweden. Statistics indicate that the costs for producing buildings have increased strongly in recent years. Figure 1 shows how the building price index with deductions for subsidies and consumer price index has developed since 1989 for multi-family housing and small group houses. These statistics have also been questioned, for one reason because a greater number of exclusive tenant-owned flats have been built than has been the case earlier. According to Statistics Sweden (2006), the variations in the building price index have to do with the fact that subsidies have varied strongly over time. The rise in market prices in recent years is directly reflected in this type of statistics.

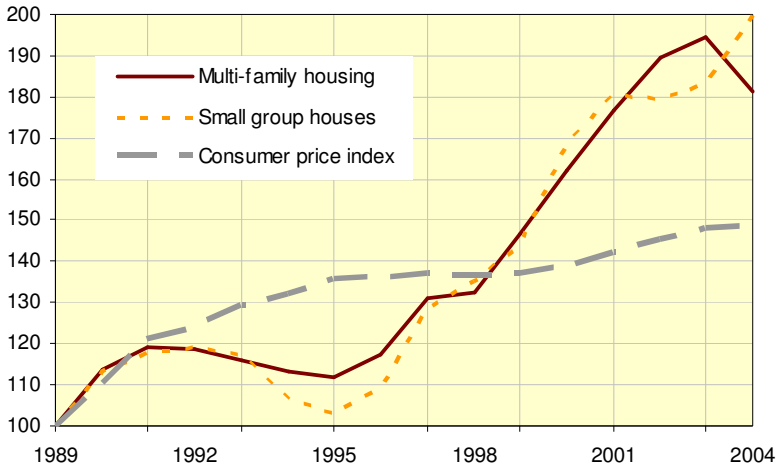

Figure 1 Construction price index 1989-2004 with deductions for subsidies and consumer price index (Statistics Sweden, 2006).

The current cost situation is also defended with statistics that show that building costs in Sweden are on about the same levels as in other comparable countries. Figure 2 shows for example that the cost for building multi-family housing in Sweden, excluding land, costs for future building owners and value added tax, is lower than in many other European countries.

Regardless of how prices and costs have changed over time and how well they stand in an international comparison, we argue in this report that all the actors that cooperate to produce buildings carry out a large number of activities that do not add any value at all to the product.

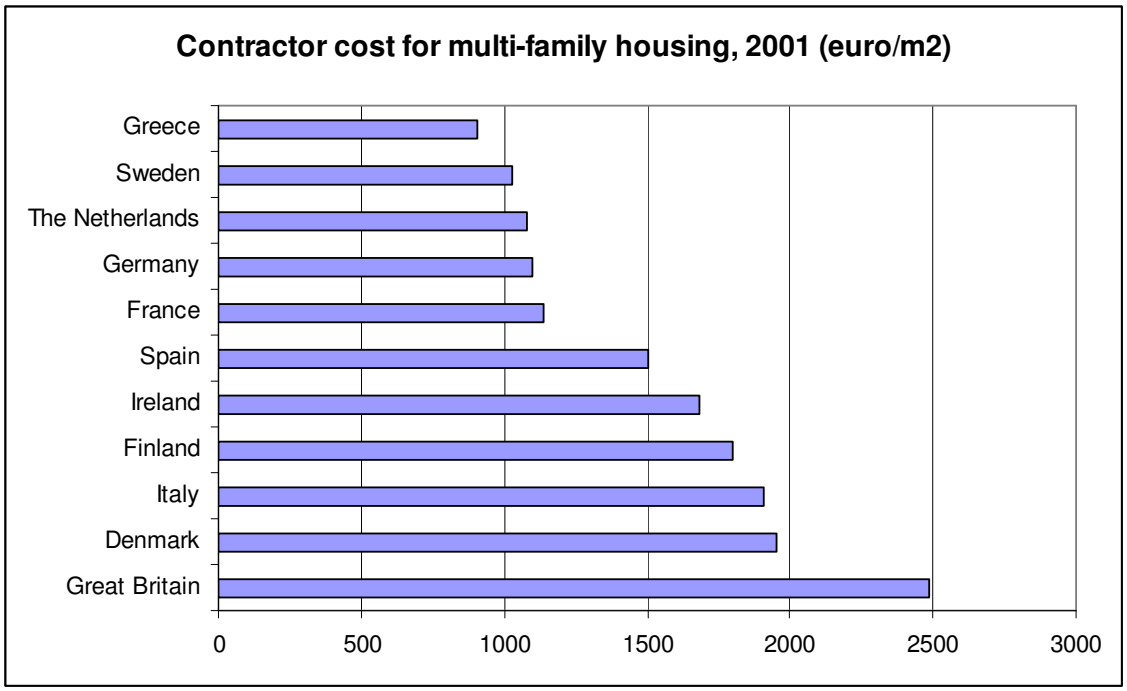

Figure 2 Contractor cost for multi-family housing per square meter, excluding land, future building owner costs and value added tax, in a selection of European countries (based on the Swedish Construction Federation, 2005, in Gardiner & Theobald).

National initiatives and differing opinions – do we forget the waste?

High costs for construction are discussed in many countries around the world. The construction sector is criticised for being ineffective, underdeveloped, corrupt and many other negative things. A number of national initiatives have been taken to improve its image and effectiveness, of which the British improvement program Constructing Excellence – often called "Rethinking Construction" after the report that initiated the program – has drawn the greatest attention and become a model for other national initiatives.

The Swedish government recently initiated a number of investigations to study relevant problems in the construction sector. Byggkvalitetsutredningen (1997) focused on general problems related to quality. Byggkostnadsdelegationen (2000) focused on what was considered to be high costs. Byggkommissionen (2002) treated general problems. While these three investigations have been criticised by the industry and by researchers, they have also led to a large number of federal and private initiatives whose purpose has been to solve one or more of the sector's problems. Among federal initiatives, we can mention the establishment of the Forum for Building Costs at the National Board of Housing, Building and Planning, which works to reduce the costs of construction of new rental homes, and the establishment of the Swedish Construction Committee, whose task it is to "together with representatives of the building, real estate and design sectors build up and coordinate a development program for the sector" (The Swedish Construction Committee, 2004).

In this debate it still seems that several groups of actors agree that costs can actually be cut. However, they often disagree about which cost elements should be

reduced, as they often have different opinions about what the causes of the cost level are. Disagreement sometimes has to do with politics. The Swedish Construction Federation argues for example that taxes on construction are far too high, while other actors speak about the excessively bureaucratic management of federal authorities, clients' demands for extremely short construction times, the far too complex organisation of building projects, the exceedingly ineffective production of building contractors, the low competence in the sector, the high prices of material suppliers, the excessive power of union organisations and so forth.

However, the national investigations, national initiatives and actors' arguments about what the causes of this situation are have in common that they seem to forget that there are a number of activities that are carried out without their adding any value to the product that is delivered to – and is paid by – the customer.

Five, ten and now thirty percent – how does that make sense?

Several different understandings and different information circulate in the debate concerning what improvement potential there is in terms of decreasing waste. There is great confusion sometimes, even among researchers. One company's development manager told us that "ten years ago you taught us that we waste 5%, now you say 30% - how does that make sense?" The explanation for the confusion is that information comes from investigations in which the definitions, perspectives, viewpoints, scopes, methods etc. are different, sometimes in very significant ways. The concepts also cause confusion, as studies of defects, deviations, disturbances, deficiencies in quality and waste are compared as though these concepts were synonymous. The head of one company who was interested in development told us that "a professor said to me that it's called cost for defects, not poor-quality cost". These concepts do not have the same meaning, however.

Definition. Some studies include changes and others do not. Certain studies classify the entire amount of work that results from sub-optimal geotechnical investigations as defect cost and others possibly classify defect cost as the difference between the actual cost and the extra amount that it has cost over what it would have if the original investigation had been optimal.

Method. Some studies make sporadic random inspections and others make more systematic and resource demanding investigations. Certain studies are questionnaire investigations that rely on the attitudes of different individuals, while other studies use more factual methods for data collection, e.g. direct observations of what really takes place.

Basis for comparison. It is very important whether the absolute cost of waste is compared with the total cost of the project, e.g. the production cost, or with the cost of the activities that is being studied. In other words it is possible to juggle numbers according to the purpose.

Knowledge development. A further explanation for why different information circulates is that knowledge about what is waste is successively increasing. We ourselves have reported different information. In our early studies of defects, we reported that the defect cost in building projects was about five percent, with a variation between two and ten percent in the projects that we studied. See Augustsson *et al.* (1989) or Hammarlund *et al.* (1989) for our first major study and Josephson and Hammarlund (1996; 1999) for our second major study. The defect cost here is the cost for correcting defects that have been detected at the construction site during production and is placed in relation to the

building cost. We found afterwards that we had not captured all the defects and all the costs associated with them. We thus estimated that the actual defect cost was in fact in the size of ten percent of the building cost. We discover as we go along how narrow our perspective has been and successively study more and more of the total cost picture and question more what value activities actually have. We have thus ourselves during the past 20-year period undergone a period of maturity – changed our viewpoints.

The concept of poor quality costs is now being used more often. These include costs for defects that are detected and corrected before delivery, costs for defects that the customer discovers after delivery and costs for inspections. Lost revenues resulting from defects and deficiencies are sometimes also included. In this case, numbers in the order of ten to twenty percent of the project's or company's sales are often cited. More drastic descriptions have even given thirty percent, although empirical support for this is lacking.

In this report we broaden the concepts further by including all activities that do not add value to the product that the customer has ordered.

The only thing we can be sure of is that we will hear more about the improvement potentials. What is interesting however is not primarily how high the percentage is – regardless of whether it is five, ten, thirty or fifty. It is sufficient to understand that there is a huge potential for improvement by trying to decrease waste; and it is significantly more important to understand what waste really are.

Purpose of the study

The primary purpose of our study of waste – and of writing this report - is to stimulate the debate about the size of costs for construction. A second purpose is to give a foundation for directing improvement work towards more effective measures. A third purpose is to help speed up the change in views that we believe must take place in order to bring about a successful construction sector. We do this by identifying and quantifying costs for the kind of waste that adds to the cost of building projects.

We take a clear customer perspective and base our conclusions on the customer's wallet since all waste has an effect on this in one way or another. We thus follow what the money that leaves the customer's wallet is being used for.

The study is limited for practical reasons to the costs that arise during the period until the building is finished and will be used. In the use phase, a number of other costs arise as a result of defects during production. Shorter studies indicate however that waste in the use phase is of similar size as in the production phase.

2 Concepts and approaches

Types of processes and wastes

All types of activities can be described in terms of processes. Processes are usually divided into three categories:

- *Operative process:* A series of activities (work elements) that directly add value in the viewpoint of the customer. If an activity that is a part of the operative process is taken away, the product or service will be incomplete.
- *Support process:* An activity or series of activities that support the operative process. They do not themselves add value to the product or service but are more or less necessary for the operative process to function.
- *Management process:* An activity or series of activities whose purpose is to determine the organisation's goals and strategies.

Waste exists in all these categories. In the operative process, the activities can perhaps be carried out in another order and in this way free up time or the activities may include corrections of defects. In support processes and management processes, there may be routines that added value at one time but have now lost their purpose.

Waste is particularly discussed in the area of lean production, a philosophy based on the work method used at the Toyota car manufacturing company. Womack and Jones (1996) define waste in the following way

"Waste is any activity which absorbs resources but creates no value."

Problems can arise in determining whether support and management processes should or should not be classified as waste. For this reason we use the concepts of value-adding work, preparation and waste here. Preparation refers to processes that are necessary for the value-adding work to be carried out. Waste is waste that lacks a connection to value-adding work. A basic idea is that improvement work should primarily focus on eliminating waste and secondarily on trying to make preparations more effective.

The Toyota CEO Taiichi Ohno was the first to divide waste into categories. He pointed out seven categories of waste. Researchers and organisation consultants later identified further categories. Examples of categories of waste are:

- Defects in products
- Storing materials and products that wait to be treated
- Waiting among personnel
- Activities and sub-activities that are not necessary
- Personnel walking around without a clear purpose
- Products and services that do not meet the customer's demands
- Over-work – carrying out more work than the customer demands
- Unnecessary movement when personnel carry out their jobs
- Over-production – manufacturing or producing more than is necessary or than has previously been needed
- Rework
- Transports of materials
- Material waste

- Work carried out in the wrong order
- Too large work force

We see from these examples that the philosophy is often applied in order to make production more effective. However, we find similar examples in design, purchasing and many other processes and activities that use resources and thereby add to the customer's cost.

A customer focus

The concept of waste has certain similarities with the use in quality management systems of the concept of costs for poor quality. According to the literature, there should in both cases be a clear focus on the customer in order to determine what is waste and what is costs for poor quality. When the concepts are used in practice, however, it is common that the focus is only on a company's internal activities. If we instead use a clear customer focus, we find activities in industry and society that are generally accepted but that directly or indirectly increase the costs that customers bear without there being greater value to the customer. The systems used in industry in a certain country can include activities that can be seen as waste. To improve competitiveness, it is necessary to use as a basis what the customer pays and how this money provides greater value. This is necessary not only to the industry – it is also necessary for companies that want to achieve world class competitiveness. This focus on the customer, which also takes into consideration processes outside direct suppliers, makes it more difficult to measure the total waste; on the other hand, this view means that knowledge can be gained about new and previously neglected areas of waste.

The concept of "customer" is used somewhat differently depending on the context. The traditional definition of a customer is the one that "receives a product or service". A broader definition includes all those who, as a customer, in some way are affected by the product or the activity. We use a traditional view and see the client of a building project, i.e. the client, as the customer. This means that our point of departure is all the costs that the client has or expressed in another way; all money that pass through the client organisation.

Cost concepts and cost distribution in buildings

Below we will use the following concepts and cost distributions, which we have taken from the Swedish Construction Federation.

Production cost is the total cost of a building project when all steps in the building process have been included: land acquisition, design, municipal fees, checks, inspections, guarantees, insurances, interest on the letter of credit, contractor work and value added tax.

Future building owner costs are primarily design, letter of credit, insurances and the future owner's own administration.

Construction cost (cost for construction) has to do with land and excavation work, erecting the building and rough and detailed planning of the land. The construction cost also includes connection costs for electricity, district heating and cable television.

Cost element	*Proportion of the production cost (%)*
Value added tax	17
Future proprieter costs, incl land acquisition and municipal fees	22
Construction cost	61
Transport, machinery, operating expenses	17
Materials	28
Wage cost – non-manual workers	4
Wage cost – craftsmen of the subcontractors	4
Wage cost – construction worker	8
Total	100

Figure 3 Distribution of production cost for new multi-family housing (taken from the Swedish Construction Federation).

3 Method and design

The study was carried out in three stages: identifying waste, quantifying waste and formulating proposals for countermeasures for decreasing waste. The study was guided to a certain extent by the fact that the major part of the data was collected in four housing projects.

Identifying waste

We first made a study of the literature and held eleven group discussions to identify as many examples of waste as possible. Four group discussions were held with six to nine individuals from each of the four construction companies that actively participated in the study. Each company selected individuals with different work responsibilities and roles and invited them to a meeting in the company's own premises. Seven group discussions were held with three or four individuals who were clients, architects/design engineers, installation consultants, project managers/building managers, installation contractors, finishing contractors, e.g. painters, and material suppliers. All meetings lasted for about two hours and were led by us.

The group discussions had the form of brainstorming meetings. When we had described the purpose of the study, we asked each participant to write down as many examples of waste as possible on Post-it® notes. Each participant then reported what he/she had noted by putting one note at a time on the wall and explaining the particular waste. The participants were encouraged during this time to continue to write down further examples. When all the notes had been presented, an overall discussion was started about the different kinds of waste, e.g. about what had been identified and what had not been identified. These meetings generated a total of 750 examples of waste – or at least what some individual considered to be waste – that should be eliminated from the process.

Quantifying waste

The quantification of waste was connected as closely as possible to four building projects, which were selected by the companies that participated. The reason for tying the study to specific projects instead of making broad, general questionnaire studies, for example, was to achieve clearer examples.

The examples of waste that emerged in the brainstorming exercises were sorted into suitable areas. The study's project group then judged which areas were most important to study and which were the simplest to study. In a first phase, these areas were divided so that we researchers made special literature searches in the areas that had already been studied while the companies took the responsibility for collecting information in areas in which they were especially interested. The different inventories were carried out according to the particular type of waste. Results of these inventories were then presented at the project group meetings in order to test the results and broaden viewpoints so that as many parts as possible of the waste in the specific area were registered. In a second step, the areas that had been given medium priority were divided between the companies for new inventories. A questionnaire on all the areas that had been given the lowest priority was created in parallel. Key persons in the projects were identified, and the construction companies contacted them and drew up an interview schedule that the researchers then used for interviews with 43 persons in the four projects.

The members could exchanges ideas and learn from one another in regular meetings of the study's project group and thus develop new approaches and collect more detailed data. The basic data collection was adapted according to the type of waste but was often a mixture of interviews, direct observations of ongoing work, reviews of existing documents, project reports, time plans etc.

Interviews were conducted in parallel with experts from federal authorities, branch organisations, union organisations, companies and universities. In this way we were able to collect further information and ideas on waste.

Formulating proposals for countermeasures

When the main inventory was completed and the preliminary results compiled we invited those who had participated in the eleven group discussions in stage I to a follow-up meeting. We first reported on a number of examples of results of our inventories. We then led a discussion of the waste that is most simple to eliminate and how it can be eliminated. The discussions became relatively detailed and clearly showed that longer and repeated discussions were needed to understand what activities increase value in the product and what activities do not.

In subsequent work it is thus important to go carefully and systematically through what the results actually mean – understanding the results is thus a time-consuming process – and then to work on formulating countermeasures in broader groups of actors.

PART I:

EXAMPLES OF WASTE

4 Defects and checks

An obvious group of waste is the consequences of specific defects, i.e. defect costs. The hidden defect cost is greater than the visible defect cost. Because defects occur, checks are created to discover them and insurances are taken to spread the risk. Thefts and destruction of property are seen as defects incurred by external parties.

Defect costs during production

Time and costs to correct defects are the types of waste that are most often discussed. It is clear that these do not add value to the product. We differentiate here between visible and hidden defect costs. Visible defect costs are the costs for defects and their consequences that we with our present knowledge and measurement methods can capture and register. Hidden defect costs are consequently costs for the defects and their consequences that we neither have the knowledge nor the measurement methods to be able to capture. By developing knowledge and measurement methods, hidden defect costs can be made visible, thus increasing the possibility of reducing them.

Through the years a number of studies of visible defect costs have been made, although with extremely varying precision. The most comprehensive study to this time was made by Chalmers University of Technology in collaboration with R&D West at Swedish Construction Federation in 1994-1996 (see Josephson and Hammarlund, 1996; 1999). The following results are based on this inventory. Registration of visible defect costs and an up-to-date evaluation of hidden defect costs show that defect costs during production, excluding costs for changes and additional work, accidents, defects detected in inspections and thefts, were in the size of 6-11% of the project cost. This corresponds to about 3.5 – 6.5% of the production cost of a project.

Visible defect costs

The study followed seven housing projects for a period of six months each. An observer was present fulltime at each of the construction sites. 2879 defects were registered and analysed considering causes and consequences. The defect cost in the seven building projects varied from 2.3% to 9.4% of the project cost. If we neglect changes and additional work, accidents, defects detected in inspections and thefts, which we treat in separate sections, the defect cost varies between 2.3% and 8.1%, see Figure 4. Only 79% of the defects noted were corrected such that the final solution agreed with the intended solution. Several of the remaining defects can have effects during the building's utilisation phase.

Hidden defect costs

The study confirmed that the observer was not able to register all defects that occurred, that the observer was not either able to follow up all the consequences of the defects, that the sub-contractors' work was followed up to a lesser extent, and that costs for defects that are corrected at the manufacturer are hidden because they are included in the price at the purchase of building materials and equipment, as in leasing machinery and equipment.

A point of departure in our evaluation of the hidden defect costs is the visible defect cost that is associated with the building contractor's processes at the construction

site, which varied between 5.3% and 9.2% of the cost of these processes. On the basis of that we made the following assumptions:

- The cost of defects during the manufacturing of materials at the manufacturer and possible intermediate storage is 5% of the building contractor's purchase price.
- The cost of defects during manufacture of machinery and equipment and during the handling of these is 5% of the building contractor's purchase price or leasing price.
- The cost of defects in the sub-contractor's processes is at least 80% of the cost of the building contractor's processes at the same construction site.
- The cost of other undiscovered defects is 10% of the visible defect cost. The observers estimated that they had succeeded in registering 60% - 90% of all defects and a somewhat higher proportion of the actual defect cost.
- The cost of undetected consequences is 5% of the visible defect cost. Special analyses of individual defects clearly indicate that there are additional costs that have not been registered. In presentations at industry seminars we often receive comments from practitioners that the reported cost for certain defects is strongly underestimated.
- Joint costs for establishment etc. increase by a corresponding amount of 80% of the visible defect time, i.e. the work time necessary for correcting defects at the construction site.

With these assumptions, the cost for hidden defects varies in the seven projects between 2.7% and 5.4% of the building cost, see Figure 4. Note that the cost of hidden defects is greater than that of the visible defects in five of the seven projects.

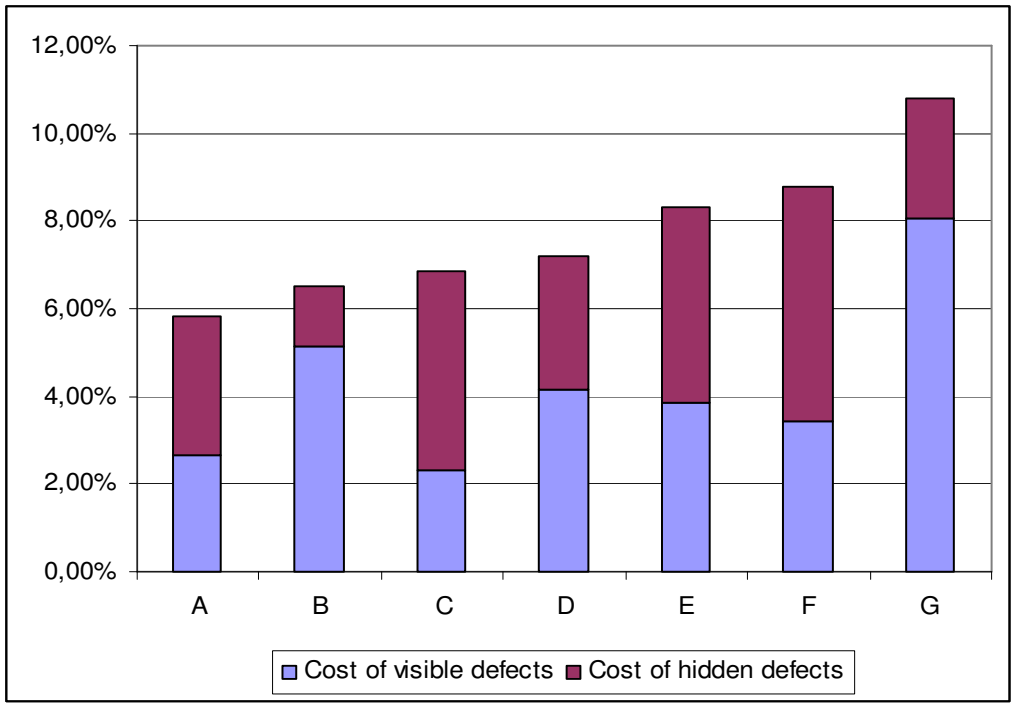

Figure 4 Costs of visible and hidden defects during the production phase in seven building project, excluding changes and extra work, accidents, errors detected in inspections and thefts (% of the construction cost).

Checks and inspections

The reason that checks and inspections of various types are made is that there is a risk that work is not done correctly the first time. If this risk for defects disappeared, the need for checks and inspections would also disappear and thus all work related to these activities is classified as waste.

The first costs related to checks and inspections are designing and managing the inspection activities. The internal activity consists for example of the project's own checks, measurements and coordinated testing. External checks can for example be carried out by chimney-sweeps, emergency services, energy authorities and the Postal Service. Finally one or more inspections are made by the customer. The work of all these actors is paid for in the end by the customer. To gain an understanding of the scope, we carried out interviews in the four building projects. The interviewees were asked to estimate the amount of time that was necessary for inspections in their own organisation and for the building project as a whole. A summary of these estimations shows that the cost of checks and inspections is approximately 0.2% - 1.5% of a project's production cost.

We received the most comments on the project's own inspections, whose use was questioned – "they should be done for the company's own sake and not for the client" – and on the final inspection, where a number of contractors are involved for a period of one to three days in a kind of troop. In one medium size building project, 15 individuals participated in a two-day final inspection, i.e. 30 work days. The building contractor spent a further 20 days on a pre-inspection and 12 days on managing the results after the final inspection. It should be noted that the final inspection is primarily an external inspection and does not examine what is hidden behind surfaces.

Thefts and destruction of property

Thefts and their consequences are phenomena about which organisations do not have complete knowledge. It is clear however that thefts cause costs that do not add any value for the customer. These costs are thus classed as waste.

Thefts cause costs of different kinds. First, there are costs for the equipment that has been stolen and the time required to acquire new equipment. This time can possibly also result in a stop in production. There are costs for internal reports to the organisation and to the police. The costs for the work of the police and the judicial system are also indirectly paid by the customer via federal taxes. Furthermore, many different kinds of insurance must be held owing to the risk of theft.

Over and above the costs described above, there are also costs for prevention, such as alarms, security services and the time it takes to move equipment to safer places. If there was not a risk of break-ins, the costs for secure locks and protection systems would also be able to be strongly reduced. All the above costs exist as a result of theft and are thus classed as waste.

A study by Munthe et al. (2002) estimated on the basis of interviews the costs for most of what is mentioned above at building sites. The study shows that thefts and their consequences correspond to 0.88% of the contractor's price, but it is pointed out that the actual numbers are probably higher. Munthe et al. did not include in their study thefts outside the building site, for example at the material suppliers and in the planner's offices. According to the interviews in our study, thefts give rise to costs of at least as large an amount of the turnover at e.g. the material suppliers. It is thus reasonable to

estimate the total amount of waste caused by thefts at 1% - 1.5% of a project's production cost.

Further examples

There are further examples of defects and inspections beyond those already mentioned.

Defects in early stages, including design, of course exist. The architect's producing different drawings/sketches are however *not* seen as waste here.

Defects detected in final inspections are defects or failings that must be corrected. These are therefore waste.

Insurance is in itself waste. For a normal project, the total premium for the building contractor's insurance is 0.5% - 2.0% of the project's production cost. Added to this are insurance premiums for each further company involved in the project. The building contractor listed the following insurances: liability insurance, including product liability insurance, consultant liability insurance, contractor insurance, comprehensive insurance for permanent plants and buildings, consequential loss insurance for permanent plants and buildings, property insurance, office insurance, insurance for registered vehicles, tool insurance, official insurance, construction defect insurance, general company insurance, third-party liability insurance, liability insurance, bank guarantee, future proprietor liability insurance.

We received several comments on the *construction defect insurance,* which costs 0.5% - 1.0% of a project's production cost. This is paid before construction starts but becomes valid only after the expiration of the guarantee time, i.e. three to four years after its payment.

The future building owner's costs include costs for several additional insurance policies and further inspections, e.g. costs for inspectors.

Computer errors. Many examples have to do with computers and computer management. These include computer problems and slow computer systems that create long wait times and delays, computer-based control systems without standards, and programs that are never used. "The number of programs tends to increase so that it's sometimes necessary to clean out programs. I removed 75% of the programs a while ago and there was hardly anybody who complained," said one of the information technology coordinators.

Changes and extra work are common and give rise to a great deal of discussion. We neglect here the changes that are caused by unanticipated changes in the customer's activities. The defect cost study described above included changes that were classified as defects in early phases. The cost for these varied between 0.1 and 0.4% of the construction cost of the projects studied. The total cost for changes and extra work was many times greater in all of the projects. Furthermore, we received several comments on revisions and PMs during the tender period.

5 Use of resources

The second group of waste has to do with how the three resources of work time, machinery and building materials are used. This group includes wait time, machinery not in use and material waste.

Work time

To gain an understanding of waste in work time we chose to follow individuals during the work day to see what they do, e.g. how much time is devoted to work that increases value. We report examples here of how construction workers, site managers, architects and technical consultants use time.

Construction workers' work time

The way skilled workers use their work time is particularly interesting since it can be seen as a reflection of how well the project organisation, production management and production planning function. Our example is taken from construction of new homes. A trained observer followed a group of construction workers for a total of 22 work days.

Work time was divided into three parts according to the value that the work give the customer. The first group is *work that directly increases value,* which thus includes such work that directly adds value to the product. In our example, work that directly increased value was done during 17.5% of the work time, see Figure 5.

The second group was *preparations,* which includes activities necessary to be able to produce but that in themselves do not increase value in the product. This preparatory work was carried out during 45.4% of the work time. Indirect work, which accounted for about 25% of the work time, includes all types of preparatory work within a few meters of the work place, primarily handling materials and equipment at the work place and work with temporary arrangements, including protection work. Material handling, which mainly includes transporting materials to the work place, took 14% of the work time. The construction workers were busy with planning work during 6% of the work time. Some activities within this group are made because of defects. This means that certain parts of this category are in fact waste.

The third group is *waste,* which includes activities that are unnecessary and that can be eliminated without having any effect on the product at all. In our example, 33.4% of the work time was waste. This includes reworking, waiting, unutilised time and interruptions. About 23% of the work time was wait time. This is primarily time for moving between work places. About 10% of the work time was unutilised time, which was mainly moving to and from sheds during breaks but also included failing to keep to schedules. There were few interruptions of work.

The results can be considered to show a surprisingly low proportion of work that increases value in comparison with international studies. An important difference is that we drew a clear boundary between work that in fact increases value and work that does not.

Looking at these results we can argue that the effectiveness is low. However, we can move the discussion a couple steps further and discuss what the situation is in the entire company. During the time of the study about 6% of the workers were on sick leave in the company in question. If we include these workers, we can claim that the work done by the construction workers that directly increased value was 16.4%! In the

next step we can also include site managers, whose work time can be classified as preparations because their task is to support production and thus the skilled workers. In our example there was an average of one work manager present per 4.5 skilled workers during the time of the study. If we also take these individuals into account, we can claim that the effectiveness is as low as 13.4% of the total time at the building site. This means that between six and seven persons are needed for each person who carries out work that increases value!

Similar studies have been done in Sweden that have examined plumbers and special contractors but have used another classification of work time. After a comparison of methods, classifications and results, we judge that waste in these cases is of the same size as in the case of the construction workers. If we assume that waste is 33% for all construction workers and assemblers, this corresponds to about 5% of a project's production cost.

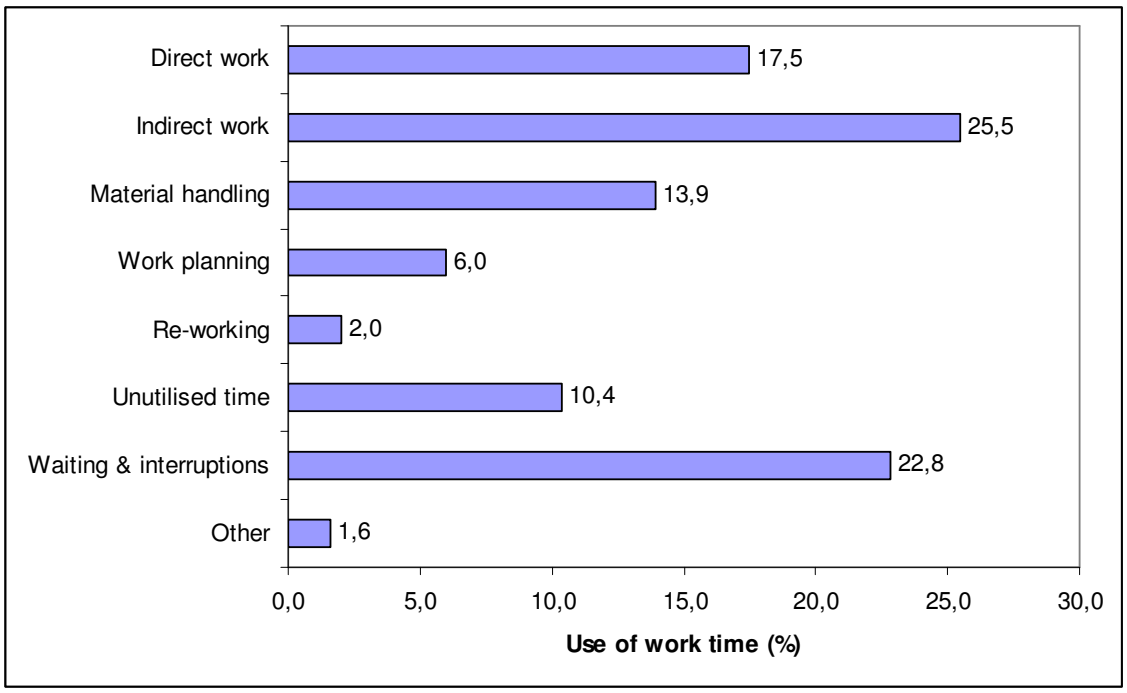

Figure 5 Use of work time among construction workers (proportion of work time, %)

Site managers' work time

Construction managers often complain that the work day consists of many unexpected events that must be dealt with. In a systematic inventory of the work day at the end of the 1990s, it was found that only 2.3% consisted of solving emergency problems (Josephson et al., 1998). On the other hand, 33% consisted of unplanned meetings. In a review of the results we find six activities that can be classified as waste. Together they correspond to 17.7% of the work time, see figure 6.

If this situation is characteristic for all contractors' managers it corresponds to 1% of a project's production cost.

Activity	*Proportion of work time (%)*
Moving about at the work place	5.2
Moving about outside the work place	4.1
Checking own work	3.7
Solving emergency problems	2.3
Waiting	1.4
Checking sub-contractors' work	1.0
Total	17.7

Figure 6 Waste in site managers' work day

Architects' and technical consultants' work time

The cost of design represents as much as 5% of the production cost. To study the use of work time in design we followed five architects with different roles and five technical consultants with different roles during one work day each. At the initial meeting we together created a categorisation on the basis of what they considered themselves to work with. A special observer then followed the individual during the entire work day and noted what the individual did exactly every second minute.

It was found to be difficult to determine what increases value and what is waste in these types of creative work. A search for a suitable solution where e.g. the architect draws up a few different proposals in order to move discussions with the customer forward can hardly be classified as waste even if all the drawings are rejected. Most of the time was devoted to work with drawings and internal discussions, see Figure 7. However, there were also interruptions, wait time and a certain amount of re-working. With the assumption that waste is in the same order as for site managers, we can claim that this waste corresponds to as much as 1% of a project's production cost.

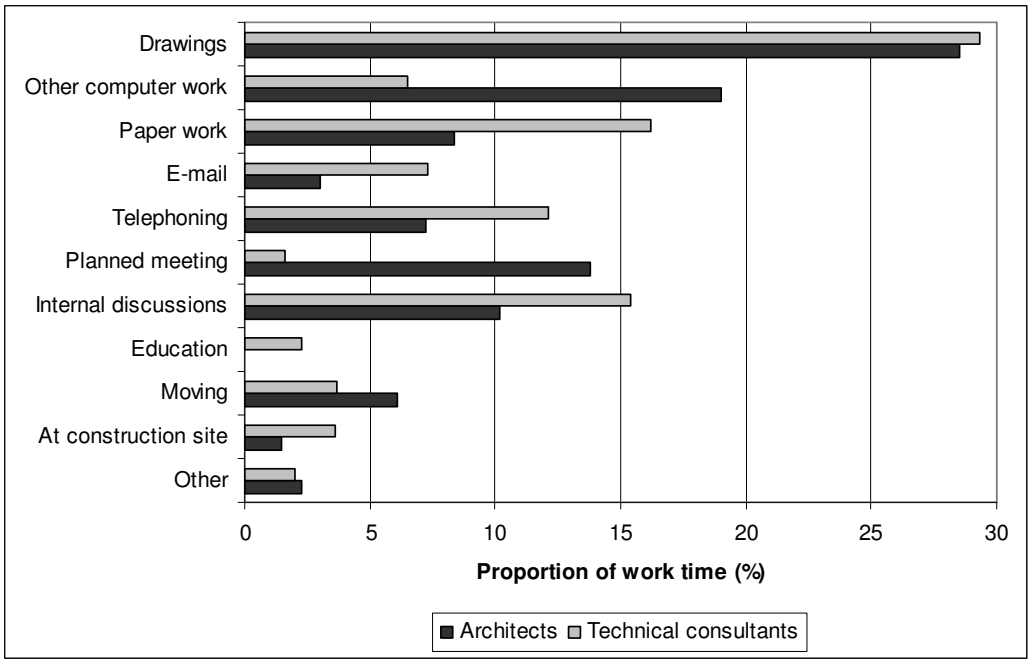

Figure 7 Distribution of work time among architects and technical consultants

Work days with many interruptions for all workers

Several investigations show that a typical work day for a manager generally contains a number of disturbances and a constant change of work tasks. Our inventory shows that this constant breaking up of work also applies to other groups of workers. Figure 8 shows a typical eight-hour work day at the construction site for a construction worker, divided into two-minute periods and excluding stops for coffee and lunch breaks. In this example, the construction worker changed tasks 156 times during the work day. It is seen in the figure that

- the work day begins with changes between material handling (code 31) and moving between work places (code 57)
- moving between work places (code 57) takes place 28 times during the day
- work that directly increases value (codes 11 – 13) is done on 32 occasions during the work day and these occasions are never longer than ten minutes.

The figure shows observations made only every second minute. The work day is in fact even more broken up!

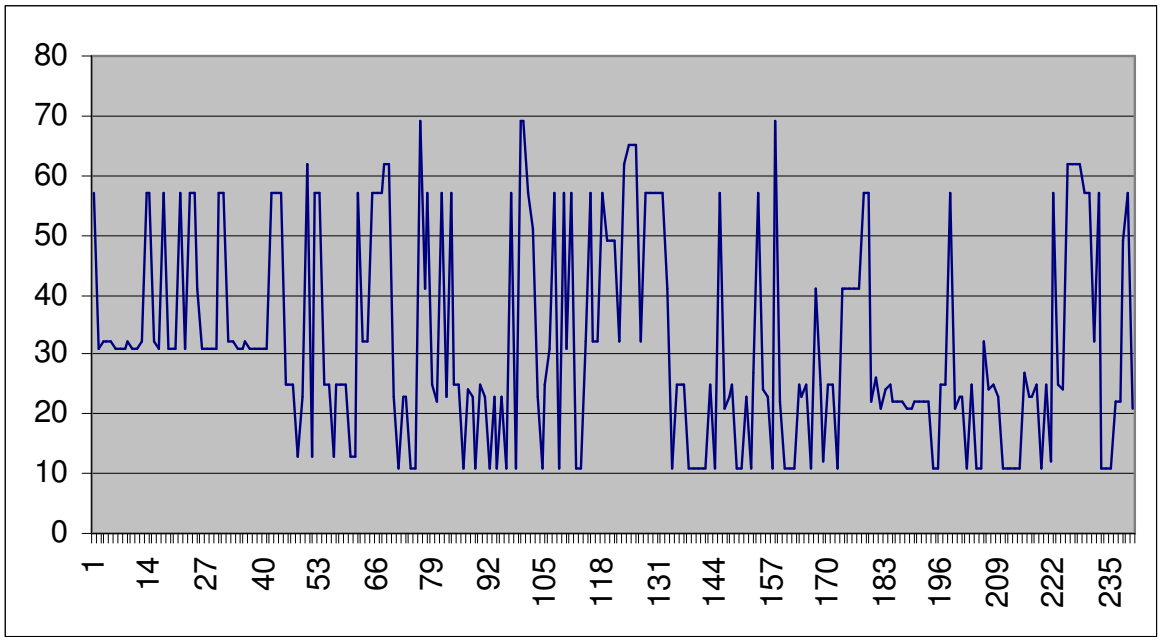

Figure 8 A typical eight-hour work day for a construction worker. The horizontal scale shows the time of the day, indicated in the number order of the observation, i.e. two-minute periods. The vertical scale gives the code of the activity (11 – 19 work that directly increases value, 21 – 49 preparations, 51 – 79 waste).

Machinery and equipment at the construction site

The cost for machinery and equipment, including common costs for sheds, containers and scaffolding, represents about 10% of a project's production cost. To find out how this production resource is used we followed a number of larger and smaller pieces of machinery during a work week and registered every second minute what each respective piece of machinery was being used for.

In excavation and pipe-laying work we followed one dumper (Volvo BM6300), one loading shovel (L25") and one excavator (5.5"). The latter was however followed during only one work day. For construction above the ground we followed two stationary saws. Here we also followed a mobile crane (50 tons) during the 11.5 hours it was at the construction site, not counting transport to and from the construction site. We further followed the uses of a hand-held drill, two compass saws, a circular saw and a power screwdriver during one work day. These pieces of machinery are parts of a carpenter's personal equipment.

In our example, the four larger pieces of machinery were used an average of 28.4% of the work time, where the dumper was used for 48.8% of the work time and the loading shovel only 6.7% of the work time. The smaller machines were used somewhat less than 5% of the work time, see figure 9. This means that the waste associated with machinery and equipment is about 2- 5 % of a project's production cost.

The observer reflected upon a number of questions during the follow-up, such as

- "Why isn't radio communication used to make cooperation between the crane operator and carpenters easier?"
- "The mobile crane is in place and waiting for the delivery of lumber. Can the lumber delivery be made at a more exact time so that the crane can be used more?"
- "Why aren't there more 'slings' so that preparation can be made for the next lift while the crane is lifting?"
- "Why is there no one to prepare the work on the site by starting up, uncovering machinery etc. so that it doesn't take so long to get things started?"

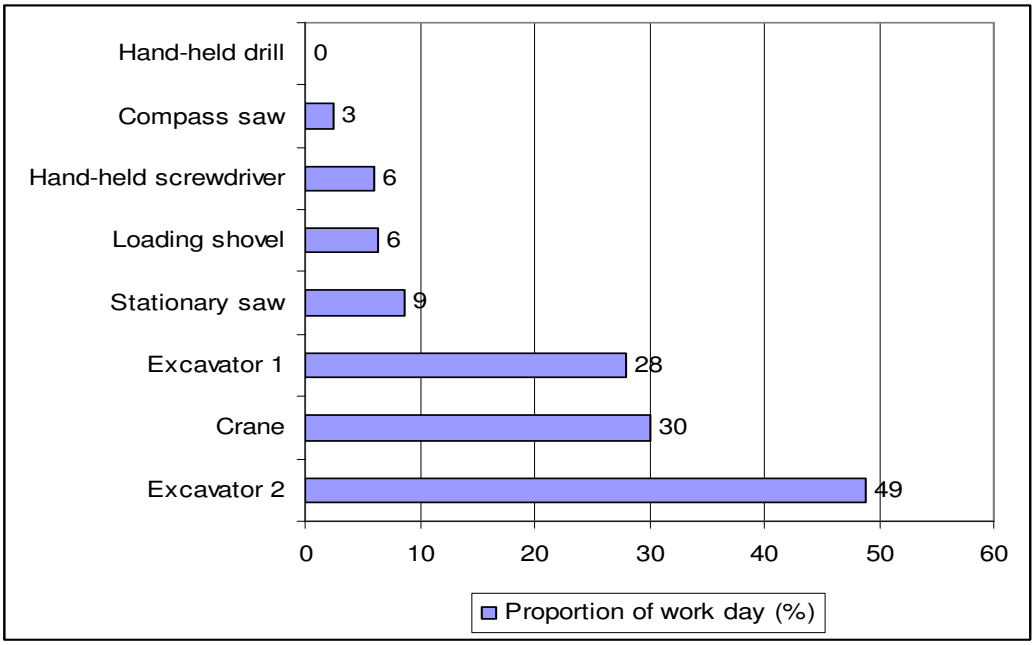

Figure 9 Use of machinery (% of work time)

Does the week consist of 40 or 168 hours?

At most construction sites work is done during five eight-hour work days, but the machinery is at the site for 168 hours every week! The same is true for sheds and other non-mobile equipment.

If we base our calculation on all the hours of the week, this means that the four larger machines in our example were used an average of only 6.8% of the available time, while the smaller machines were used only 1.2% of the available time.

We can compare with e.g. the aeronautics industry and taxi branch, where the machine itself is a large portion of the total cost and where effort is made to have it in use as much as possible. Airplanes have to be in the air as much of the time as possible. Taxis often have two drivers who can take turns driving according to an agreed schedule.

Materials

Materials that are not used are an obvious part of waste in construction projects. An investigation was done in the middle of the 1990s at 14 construction sites concerning how much of the material delivered was actually used in the buildings. The degree of use of 15 common types of building materials varied from 79% to 96% of the amount delivered, see Figure 10. The waste thus varied between 4% in the case of particle board for flooring up to 21% for facing board (Lindhe, 1996).

To form an idea of whether any change had taken place since that investigation was done we interviewed workers at four building projects. Their feeling was that waste had decreased somewhat but that it still was about 2 – 10% of the delivered volume. A cost accountant at a building company explained that "we usually calculate 10% waste. If there's a stop in production there can be very big problems and it can be good then to have a little waste."

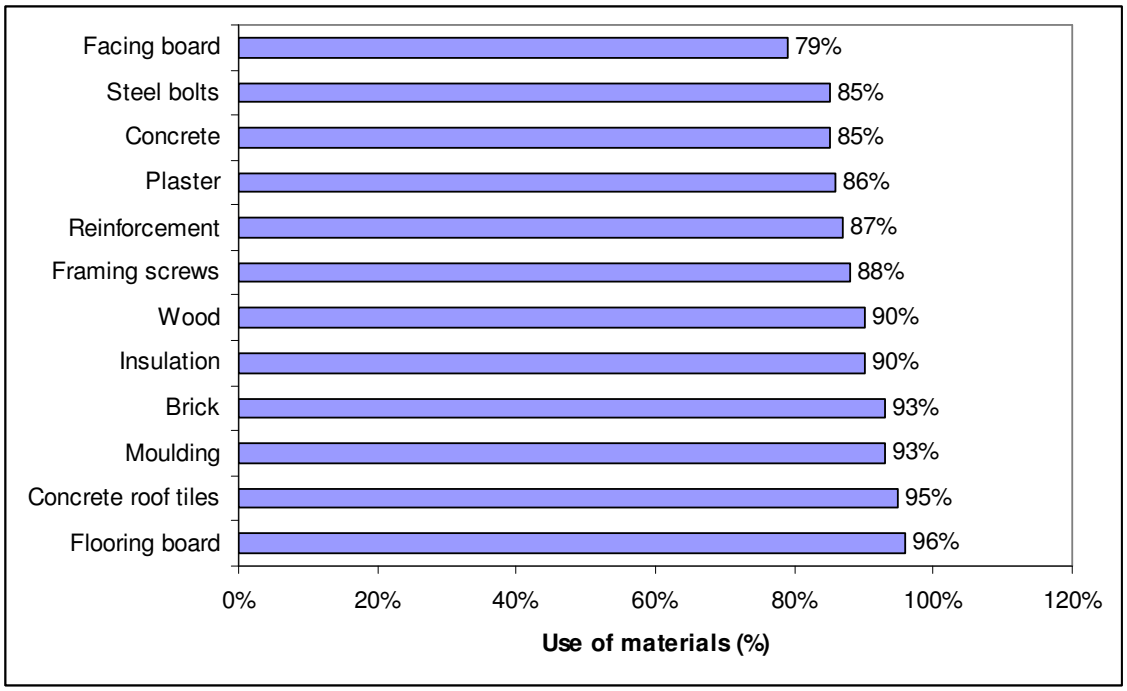

Figure 10 Average amount of common building materials used. Remaining materials are waste (taken from Lindhe, 1996).

These values however indicate only the amount of waste at the construction site. There is also waste in earlier phases in material production, e.g. in manufacturing and all other handling before the material reaches the building site. A material supplier said for example that in his company they estimate that about 1% of the material they handle disappears or has to be scrapped. Taking this into consideration, it is reasonable to assume that the cost for material waste corresponds to 4 – 12% of the total material cost in a building project. Since materials account for about 25% of the production cost, this gives waste in the order of 1 – 3% of a project's production cost.

Further examples

Meetings, transports and refuse are among the further examples of the use of resources.

Meetings upset many people who work in projects. One of the things that is disturbing is a lack of discipline. Participants often come late, causing irritating waiting for those who come on time. "There's no more lonely person than the one who comes on time to building meetings," said one actor. Another disturbing factor is the structure of the meetings, in that there is an expectation that participants will be present for the entire meeting in spite of the fact that parts of the agenda that are relevant to certain actors take only a few minutes.

In a project of new tenant-owned buildings we registered 517 meetings, of which 219 were between the broker and the customer, 170 between those who sold optional features and the customer, 11 design meetings, 33 project meetings, ten meetings with the municipality, 25 building meetings, 34 weekly meetings with foremen and 15 other meetings. A total of 3321 hours were spent in these meetings, including the customer's time but excluding the time required to call participants to the meeting, travel time to and from the meeting, time required to write and distribute agendas etc. The cost was estimated at 1.5% of the production cost. It was not possible to judge the ineffectiveness of these meetings, however.

Transports. Some transport vehicles are driven empty, which is waste.

Storing material is waste. It is common to discuss how the time from manufacturing to assembling could be minimised as well as how many occasions the specific material is stored during the process. But it is often forgotten that material which is assembled is stored until the customer begins to use the product!

Refuse and management of refuse is waste. The refuse in medium size building projects can be one container per day. "The amount of refuse from all packaging is unbelievable. There can probably be a larger volume of packaging than of material," commented one site manager. There is an understanding that refuse management and sorting refuse are ineffective at construction sites. But refuse should in fact not be transported to the construction site in the first place!

Offices, computers etc. are used during only a small part of the available time. A comparison should be made with our above reasoning concerning machinery.

6 Health and safety

The waste associated with work-related injuries and illnesses requiring rehabilitation, early retirement etc. is so large that we place this in a separate group. We have chosen to report our analysis of hidden waste in terms of taxes in this group because more than half of this waste has to do with health and safety.

Work-related illnesses and accidents

Costs associated with work-related health effects do not of course offer any additional value to the customer. The injuries, accidents and work-related illnesses that affect any employee of all those involved in the building project, and that in some way could have been avoided, are classified as waste. Colds and other illnesses that are difficult to influence are thus not included here.

According to Labour Market Insurance Company (AFA, 2004) statistics, work injuries are 50% more common in the construction industry than in other businesses. In the past ten years there has been an average of 12 deaths each year caused by accidents in the Swedish construction industry. In 2003, there were also 13 accidents per 1000 employees. 1.6 employees of 1000 became invalids. There were 8.4 cases of work illnesses per 1000 employees. 72% of these work illnesses were caused by stress-loading factors (AFA, 2004). About 630 construction workers go into early retirement each year (Samuelsson, 2004).

Work-related complaints give rise to several costs that are directly financed by the customer, primarily costs for medical leaves of absence and rehabilitation. Absenteeism also causes losses in capacity, degradations in quality, greater administration and costs for employing and training new personnel. The customer also pays indirectly, however, via taxes that are paid by society for medical care or compensation for work-related complaints.

Waste hidden in tax revenues

Companies and other organisations that measure waste in one or another form, e.g. costs caused by poor quality, almost always focus on their own activities, and in certain cases also on sub-contractors', but very seldom or never on the costs connected to the federal government's, the county council's and the municipality's expenditures. In a total inventory, however, it is important to take into account the entire cost flow through the organisation and what lies behind all of the costs. A point of departure here is that the organisation can directly or indirectly via its actions influence the total cost. Central issues that must be discussed in individual projects are e.g. what would happen in terms of a building project's total cost if:

- the number of work-related long-term medical leaves of absence and early retirements could be reduced
- the number of cases of illness and injury related to the indoor environment, traffic safety etc. could be reduced, and
- criminality could be reduced

and what the building project's organisation or the company can do to bring about changes in these areas.

The following analyses are based on the federal government's budget proposal for 2004 and the expenditures of county councils and municipalities. According to the Ministry of Finance, there is no single employee that alone can estimate the portion of waste in the federal government's total expenditures. Neither does there seem to be any employee in any of the other ministries that is able to estimate the portion of waste in the area of expenditure for which he or she is responsible. In the same way we have not found anyone able to judge the portion of waste in county councils' and municipalities' expenditures. We thus reviewed each individual area of expenditure and estimated the conceivable amount of waste. We set a lowest proportion of waste in each expenditure area of 7.5%. This is based on our own studies of construction activities where we saw that an average defect cost is at least 7.5% of the total cost. This hidden waste is so large in scope that a more detailed analysis would be interesting.

Waste in the federal government's expenditures

The federal government's budget for 2003 was SEK 715.7 billion. Our analysis indicates that waste accounts for SEK 205 billion or 30.6% of the budget. That calculation is exclusive of general subsidies to municipalities because this is treated in a later section. The greatest portion of the waste is associated with work-related injuries and illnesses, defence and the judicial system, see Figure 11. The calculation is a cautious one in many cases. Our own experience of 'Education and university research' is that a special analysis of this would give a considerably higher portion of waste than the 7.5% that we have given as a standard figure. For 'Interest on national debt' and 'Fee to the European Union' we have used the average waste in other expenditure areas as a basis.

Waste in the county councils' expenditures

The gross expenditures in the county councils were SEK 234 billion in 2003. Our summary analysis shows that waste was in the order of SEK 75 billion or 31.9% of the total expenditures, see Figure 12. The county councils are primarily responsible for managing health care and thus manage work-related injuries. 98% of the waste is associated with activities related to health care.

Waste in the municipalities' expenditures

The gross expenditures in the municipalities in 2003 was SEK 389 billion. The waste in our estimations was SEK 55 billion, which corresponds to 14.2% of the expenditures, see figure 13. The greatest proportion – SEK 31 billion or about 57% of the total waste – is associated with care-related activities. The portion of waste in pedagogic activities is more difficult to judge on the basis of available data.

Effect on construction projects

Taxes on building new housing was on average about 50% of the production cost at the beginning of 2000 according to the Swedish Property Federation (2002). This varies between projects, however, primarily because there are strong variations in the price of land. The largest proportions of tax are paid in via value added tax, income tax and social welfare fees.

The tax revenues that the federal government receives from construction and other activities are pooled and distributed to the different areas of expenditure according to need. Thus no special revenues go toward a certain specific purpose. The same is generally true for the county councils' and municipalities' revenues.

Expenditure area	*Budget (MSEK)*	*Waste (MSEK)*	*Waste (%)*
Financial security for the sick and disabled	119 399	62 751	52.6%
Defence and contingency measures	44 704	39 855	89.2%
Justice	24 585	20 593	83.8%
Interest on central government debt, etc.	54 450	16 610	30.6%
Labour market	60 307	12 559	20.8%
Health and medical care, social service	33 171	7 395	22.3%
Contribution to the European Community	23 695	7 243	30.6%
Taxes, customs and enforcements	8 266	6 613	80.0%
Financial security for families and children	52 889	4 145	7.8%
Financial security for the elderly	52 547	3 941	7.5%
International development cooperation	17 140	3 271	19.1%
Education and academic research	42 387	3 179	7.5%
Transport and communications	25 858	1 983	7.7%
Financial support for students	21 850	1 639	7.5%
Economy and financial administration	9 078	1 019	11.2%
Agriculture, forestry, fisheries, etc.	10 460	785	7.5%
Planning, housing provision, construction	9 482	742	7.8%
Culture, media, religious communities	8 358	672	8.0%
Governance	7 350	596	8.1%
General environmental protection	3 335	540	16.2%
Immigrants and refugees	7 138	535	7.5%
Industry and trade	3 543	331	9.3%
Working life	1 148	322	28.1%
International cooperation	1 285	275	21.4%
Regional development	3 608	271	7.5%
Energy	1 687	127	7.5%
Sub-total	**647 719**	**197 989**	**30.6%**
General grants to local government	68 031	0	0.0%
Total	715 750	-	-

Figure 11 Waste in the federal government's budget for 2003: areas of expenditure ranked according to the size of the waste (Government Offices of Sweden, 2003)

We stated above that taxes on new housing are about 50% of the production cost. If we add together the total waste in the federal government's, county councils' and municipalities' expenditures and contrast this with their total expenditures, we get a total waste of 27.1%, which means hidden waste corresponding to about 14% of a project's production cost!

It is difficult of course for an individual project organisation to take measures to reduce this hidden waste in a way that gives a direct and noticeable effect in any given project. Getting at these costs to the extent that the production cost is noticeably affected would require common efforts in the entire industry and society as a whole. Efforts like this are important for national competitiveness.

Expenditure area	*Budget (MSEK)*	*Waste (MSEK)*	*Waste (%)*
Somatic service	106 170	42 362	39.9%
Primary health care	48 863	20 865	42.7%
Other health and medical service	18 727	4 082	21.8%
Psychiatric care	19 771	2 966	15.0%
Dental care	8 701	1 740	20.0%
Regional development	16 142	1 211	7.5%
Traffic and infrastructure	8 814	661	7.5%
Health care in the home	2 205	441	20.0%
Culture	2 556	192	7.5%
Education	2 203	165	7.5%
Total	234 152	74 684	31.9%

Figure 12 Expenditures in county councils in 2003 (The Swedish Association of Local Authorities and Regions, 2005) and the proportion of waste.

Expenditure area	*Budget (MSEK)*	*Waste (MSEK)*	*Waste (%)*
Care	145 850	31 375	21.5%
Education	162 348	12 176	7.5%
Infrastructure	26 788	7 367	27.5%
Business activities	23 088	1 732	7.5%
Leisure and culture	19 030	1 427	7.5%
Political activities	4 606	567	12.3%
Specially directed contributions	7 499	562	7.5%
Total	389 209	55 207	14.2%

Figure 13 Municipalities' expenditures in 2003 (Statistics Sweden, 2004) and the proportion of waste.

About 52% of the waste that is hidden in the public sector is related to ill health. If the building sector succeeded in reducing its problems with ill health, taxes could either be reduced or the resources used for other more valuable activities.

7 Systems and structures

The fourth group is waste that is associated with organisational structures or management systems in federal authorities, companies and projects. This group of waste is probably the one that is most underestimated in our inventory.

Land use planning process

We received many comments to the effect that developing new land use plans takes a great deal of time, and this has often been pointed out in the daily press. We do not question the democratic process here, i.e. the opportunity for e.g. those living in the surrounding neighbourhood to air their opinions of the plan in the different phases. The waste sooner has to do with the fact that the matter "rests" during certain periods, that is, that no one works with it. Waste thus consists of interest costs on investments that are made (e.g. land) and the absence of the utility of being able to use the completed building.

We chose to study two extreme cases in the Göteborg area. In the first case, there were appeals that contributed to making the planning process unusually long. There were no appeals in the second case, to some extent because of good initial work. We clarified what proportion of the process was effective work time by interviewing 12 persons from e.g. the County Administration Board, the City Planning Authority, Planning and Building Committee, Property Management Administration, Ministry of Sustainable Development, the architect and the building contractor.

The land use planning process in the two examples took almost five years and 2.5 years, respectively. But how short can the process actually be? Plans that the Municipal Board has decided should take priority over other plans are usually processed in the space of about a year, although the process time can be shortened further if all actors treat the matter without delay and no other obstacle arise.

The example in which appeals were made during the planning process

The area had earlier been planned for office buildings. The deadline for that plan had elapsed and the building contractor wished to build housing in the area. The City Planning Authority chose in consultation with the building contractor to create the new plan according to a simple procedure. Interested parties opposed the simple procedure however and the case went to the County Administration Board (Länsrätten). While the County Administration Board (Länsrätten) judged the simple procedure to be sufficient, this decision was also appealed. The matter went to the Ministry of Sustainable Development, which decided that the approval of the plan should follow the traditional procedure. In a second round the documents from the first round were developed. The matter passed the consultations and exhibition, but approval of the plan was appealed by external interested parties. The decision is now again with the Ministry of Sustainable Development, almost five years after the project was started.

What should be noted in this case is that both appeal processes went to the County Administration Board and then further to the Ministry of Sustainable Development, and that there were lengthy treatment periods. In the first round it took one year from the time that the appeal had come to the County Administration Board until the Ministry of Sustainable Development took their decision. In the second round, the Ministry of Sustainable Development decided in December 2004, i.e. one year after

the appeal had been received, not to approve the appeal and that building could begin. Furthermore, the time it took for the County Administration Board in consultation during the second round was nearly five months, which is almost four months longer than the intention of the City Planning Authority.

Planning caused a total of 420 hours of work for the City Planning authority in terms of handling and drawings. The building contractor put approximately 300 hours into this work. The real estate registration took two hours and the description of the procedure and agreement issues took a further 18 hours. In this case the planning process would have been able to be accomplished in about 20% of the time actually used.

The example of the planning process without appeals

The building contractor wanted to build housing in an area that was planned for industry. The City Planning Authority started the planning by engaging four architect offices to develop plan proposals in parallel for a fixed fee. However, there was strong opposition at the program consultation. Important authorities put pressure to stop the project. The City Planning Authority and the building contractor nevertheless decided to try to go on with the project, although then in close cooperation with interest groups who were affected by it.

The interest groups were to take into consideration the interests of the general public at the same time that compromises were discussed with those who had objections at the program consultation. The result was a program phase that exceeded the time plan by roughly half a year, but also that no objections were raised in the planning consultation or later. The planning work was completed about six months after the intended time point.

The City Planning Authority took care of managing the planning work, and this took about 250 hours. The three architect offices whose proposals were not accepted worked a total of 870 hours. The architect office whose proposal was accepted worked a total of 500 hours during the entire planning process. The building contractor worked about 300 hours during the planning process and the Property Management Administration devoted about 40 hours. It is not clear how long it took to register the real estate. In this case the planning process could have been completed in about 40% of the time actually used.

Tender system

In the tender system, several competing companies each develop a proposal for a price and the customer chooses the best one. The idea is to achieve as good a delivery as possible for as low price as possible. In our perspective, the work carried out by the winning supplier can be accepted while the work of the other suppliers is waste. The cost for making a tender among the suppliers whose work is not chosen is paid by the customer in the long run. Smaller suppliers say that they together add about 5% of the price of delivery in calculating prices. The following example has to do with a larger project for building new housing that followed an open, competitive purchasing process via advertising. The total contract was SEK 175 million.

The purchasing process was divided into two steps. In the first, the client selected a contractor. Here, all the contractors asked for prices from sub-contractors and suppliers. In the second step, the contractor who won the bid again asked for prices from sub-contractors and suppliers in order to press down prices and decide which of the companies would get the job.

In interviews with the client and building contractors competing for the job, as well as 265 telephone interviews with invited special contractors and material suppliers, 588 (!) companies were identified that participated in the bidding process in some way. The total cost for the tender process was SEK 3.78 million, which corresponds to 2.14% of the total value of the contract, see Figure 14. Of this, the first step cost over three million crowns. A total of 8,282 hours went to this, of which more than 6,200 hours were spent in step one and the rest in step two.

The costs associated with the work of the company that won the bid corresponded to 0.76% of the total value of the contract. This means that about 1.4% of the total value of the contract, or 65% of the tender cost, can be considered waste. It is conceivable that the tender costs are higher in smaller and medium size projects. There is an understanding that the time required for handling tenders does not decrease proportionally with the volume of the project. The deliberations were considered to be good in the project considered here, which may have kept the tender costs down.

The tender system causes irritation among sub-contractors and material suppliers. Comments of the following kind are common.

> *"Estimating a tender in the first step just means a lot of work that doesn't give us anything back. It's irritating that we have to participate just to get jobs in the future."*

> *"The contractor should only contact us when they want to use us and not get us involved in the tender process."*

In an earlier study (BELAB, 1998) it was claimed that the transaction costs are probably between 5 and 10% of the total production volume (the sum of construction investments and maintenance). In the two projects studied, this cost was 4.2 and 4.8%, respectively, of the total project cost. 63% of these costs occurred in establishing the tender. Transaction costs are defined here as costs for seeking opposing parties and judging alternatives, negotiating and developing agreements and checking that signed contracts are followed. Other Swedish building companies have made rough estimations that between 4 and 7% of their turnover go to the tender process (Dubois and Gadde, 2000). Studies in Great Britain show that the costs associated with the tender vary between 1 and 15% of the turnover depending on its complexity (Hughes, 2002).

Designers tell us that that the accumulated cost for tendering for design contracts sometimes are as high as the contract sum itself!

Documentation

Many have commented on the fact that documents are developed without any clear purpose. One person responsible for purchasing at a building contractor explained that "a large number of extra documents are produced, such as environmental and quality requirements. I wonder whether all this is necessary. What does the job actually have to do with: filling in papers or doing business? You have to get rid of all these things to get anything done." There is also frustration over the unnecessary information that is sent, which one manager of a flooring company can illustrate: "The one who sent the AF [standardised project documenation] part to us didn't take away any of the material that didn't have anything to do with us, but we still have to read all of it so that we don't miss anything. A common example is that a tender of 80 pages has only five pages that has anything to do with us". Some people seem to ignore documents, such as the site

Activity	*Number of companies*	*Contract sum (kSEK)*	*Cost (% of bid price)*	*Hit rate (%)*
Clients	2	-	-	-
Designers and contractors				
- Architects and consultants	9	1,022	39.4	41
- Contractors	11	95,535	1.0	13
Subcontractors and suppliers				
- Heating, water and sanitation	13	14,835	1.1	15
- Electricity	16	10,000	1.5	17
- Control and monitoring	4	690	4.4	28
- Ventilation	12	2,462	4.4	15
- Design	2	451	11.4	-
- Concrete (elements)	9	3,257	1.5	41
- Wood (products)	25	4,124	3.0	39
- Insulation	3	-	-	62
- Steel sheet works	13	2,700	3.4	10
- Plaster works	19	10,300	2.1	31
- Paint works	13	4,837	1.3	22
- Tile works	18	3,726	1.9	26
- Floor works	9	4,411	1.2	21
- Screeding works	11	310	9.2	45
- Windows	13	5,850	1.1	11
- Doors	13	2,611	1.1	20
- Window boards	8	150	2.8	20
- Steel works	16	830	2.9	33
- Staircases	10	1,469	1.0	31
- Balcony parapets	4	1,462	2.2	50
- Fittings	6	223	4.2	52
- Kitchen fittings	3	4,990	0.2	42
- Other	15	-	-	-
Subcontractors and suppliers on second level	311	-	-	-
Total	588	176,245	2.1	27

Figure 14 Cost for handling tenders and average "hit rate" for the different categories of actors.

manager that said that "I have to say that I'm bad at reading the documents…I know that there's a load of notebooks but I don't know which they are". There are several examples where one person thinks that a certain document is very important while another thinks the same document is completely unnecessary! One project manager thought that "risk analysis, specifications, operations and maintenance booklets – all these are very useful if there are problems, so they should be there of course", while a purchaser thought that the documents and notebooks were never used. One site manager explained that "we collected 15 notebooks with self-checks (including humidity). But I rarely go and read the notebooks".

The value of certain documents can vary e.g. depending on whether or not they are used at all. To gain an idea about how many documents are developed in a construction project one building contractor made a list of all the documents they come into connect with. He succeeded in identifying 121 types of documents, of which most (e.g. minutes of building meetings) were issued many times in each project. Most of the documents were judged to require only a little or a medium amount of work to deal with, but they were also considered to give great or a medium amount of usefulness for the project. Eighteen types of documents were considered to be of little use. Three of these documents were also judged to require a large amount of work, see Figure 15.

There is an obvious risk that new documents are created for a particular purpose but are later "worked in" as a routine in all projects. An important question is thus what documents are not included in an individual project. Another question is what documents can be coordinated to reduce the total amount that has to be managed.

		Work required		
		Low	Medium	High
Usefulness	Large	32	20	19
	Medium	11	17	4
	Small	12	3	3

Figure 15 Number of documents classified according to work required and usefulness.

Further examples

There are further examples of waste beyond those already mentioned:

Piece-rate sometimes exists for construction workers and certain special contractors. The costs for measuring, making tallies and negotiating can be classified as waste. We studied a medium size housing project. The costs of the building contractor's company that had to do with piece-rate corresponded to 0.24% of the construction cost. The costs for the building union, which is taken from the wages of the construction workers, corresponded to 0.17% of the construction cost.

Trade organisations and interest associations. There are surprisingly many trade organisations and interest associations, each with their particular purpose. This is to some extent a result of the great need of specialists. There is waste here because certain trade organisations work in parallel with the same question and in that way do double work and because certain interest associations have been started for very similar reasons. The result is that companies pay many different membership fees in order to finance each of these activities. The Swedish Construction Federation's building commission (Andersson et al., 2003) comments on one aspect of the problem and suggests "more company – less industry".

Certification. We received many comments on the certification of products and management systems. The work manager at one building contractor felt that "many quality systems are created mostly for the sake of the system. If the system is adapted to the project, it can be useful. Otherwise it's mostly a paper tiger. I think a system with fewer items would be better". There are arguments in the literature and the general debate both for and against certification. A certificate in itself does not mean that the value of the building increases. In practice, the usefulness of being certified probably depends on how the company itself works with the system that has been developed.

Sander (2004) studied the costs of certification work in a few smaller companies. She found that the cost during the first year corresponded to 1.4% of the

turnover and the following years 0.4% of the turnover. Ideberg et al. (2003) analysed a medium size consulting company. The cost of implementing the quality management system was 1.6% of the company's turnover. The running costs for maintaining the quality management system and the environmental management system together corresponded to about 1% of the company's turnover. In no case was it possible to quantify the positive effects.

E-mail management. Many persons also complained about how the e-mail function is managed. They explained how e-mails go out to everyone in the company, despite their being relevant to only a few employees. It is also common that copies of e-mails are sent to several people simply for their information.

PART III:

OBSTACLES AND COUNTERMEASURES

8 Four obstacles to development

The building sector has a great potential for improvement – there is no doubt about that. To utilise this potential the sector must tear down a number of obstacles. We discuss four obstacles here.

The opinion that construction is unique and conservative

There is a broad opinion that each building project is unique, that the building sector is different from all other sectors and that the building sector is conservative. These ideas come up constantly in debates and seminars, and sometimes in trade newspapers and the scientific literature as well. What surprises us is that when we conduct interviews – focusing on various themes in different R&D projects – with representatives of nearly all actors they tell us that "all projects are unique" and that the "building sector is conservative" without us even asking about it!

The building sector tends to adapt concepts and systems that are used in other industries to their own concepts and systems. An up-to-date example related to the theme of this report is the concept of Lean Construction, which has more or less been translated from Lean Production, in other words the philosophy that is founded on the work method of the Toyota car company. It is a good thought intended to create a broader acceptance within the sector, but at the same time it strengthens the notion that building has its own culture and its own way of working.

Construction projects, both the products and the processes, are in practice actually considerably more like each other than unique. Neither have there been studies that support the assertion that people in the building sector are more conservative than others. The assertions are most probably often a defence of prevailing work methods and the unsatisfactory state of things. The first obstacle to development is that we convince ourselves that it is not possible to work smarter.

Customer focus – is it true?

Most companies in the building sector claim that they are customer oriented and that they focus on the customer. This may be true for how companies take consideration to and translate the customer's needs into qualities in the product. But it is hardly true for how companies use the money that leaves the customer's wallet.

The problem is to get those who are active in the building sector – primarily in projects, but also in companies and interest organisations – to realise that the expenditures for their work in fact burden the customer's wallet. Form a mental picture of the streams of payments that run through the project organisation, that is, from the customer via the future building owners, consultants and building contractor and further through special contractors and material suppliers. Certain streams run further to the government, county councils and municipalities, and to insurance companies and so on. Common for all these streams of payment is that they start in the customer's wallet.

We have seen that waste exists in all activities. Considering the streams of payment, this means that compensation for waste is taken out via the price of the product or service. Thus many different types of waste are hidden in the price that the customer pays. A complement to trying to develop a company's own processes is therefore also to pay attention to the internal processes of suppliers. Put another way, this means that the company should evaluate all money that passes through its own

accounts. Building companies claim that close to 80% of their commissions consist of purchased products and services. What do the processes that create these products look like? What waste is hidden in them? The Swedish Construction Federation maintains that the taxes on new housing are 65%. What processes are financed by tax revenues? What waste exists in these?

The companies (and the industry) that want to develop their competitiveness to absolute world class must broaden their own view of what adds value and what does not so that they include all the processes that hide behind the streams of payment that pass through their ledgers.

This weakness in the customer focus is the second obstacle to utilising the entire potential for improvement.

Improvement work often leads to more administration

The improvement work that individuals, groups, companies and industries initiate and conduct is well meant and its purpose is in different ways to produce better buildings at a lower cost. However, a review of different forms of improvement work shows that they often lead to a greater amount of administration and higher costs. New documents and activities are added to the process, but few old documents and activities are taken away. The third obstacle to utilising the improvement potential is that improvement work – in spite of good intentions – often works against its own purpose by increasing administration. Let us look more closely at some forms of improvement work. We have chosen to take examples from three worlds that our co-workers in the study's project group, our financers and we as researchers work in.

The example of discovering defects earlier

On one occasion we allowed four experienced individuals, an architect, an installation consultant and two building contractors, to analyse descriptions of about 200 defects that were particularly expensive to correct. Common to these defects was that they were detected at a late stage. Part of the analysis consisted of judging "what would have been necessary with a reasonable amount of work for the defect to have been discovered earlier". We received a total of 512 suggestions that we were able to classify into four main groups: developing individuals' qualities (e.g. giving more training), improving activities (e.g. doing more planning), creating routines and supplying resources. All (!) of the improvement suggestions required an increase in support processes. Not one suggestion meant in itself a simplifcation of a process.

The example of federal investigations

Similarities were seen in some public federal investigations. The Building Commission's report "Shape up, chaps…" (SOU 2002:115) gives 22 suggestions. Fifteen of them meant that support processes would be expanded, such as "…design a training session…", "…develop a system for official statistics…", "…establish a building damages commission…", "…write instructions…" and "…set up a scientific council". Only one (!) suggestion implied a simpler process. The remaining suggestions are difficult to judge.

About the same imbalance exists in the suggestions given in the Construction Cost Delegation's report "From building sect to building sector" ("Från byggsekt till byggsektor", SOU 2000:44). Of the 31 suggestions given for long-term reductions in costs for production and administration for housing, 15 implied greater support

processes and four suggestions a simplification in processes. Twelve of the suggestions are more difficult to judge.

The example of management researchers' recommendations

We analysed 204 articles published during 2003 in three scientific journals, of which two are oriented toward construction (Construction Management and Economics, ASCE Civil Engineering and Management) and one was project oriented (International Journal of Project Management). Of these, 145 contained recommendations to the building and real estate sectors. Eighty-nine of the recommendations implied expanded support processes, 34 no change in administration and 22 simplified processes. In other words, it was four times more common for the researchers to give recommendations that increase support processes than that simplifies administration.

The structure of the construction sector works against development

In carrying out this study we saw time and again how the building sector's structure with many actors splits up the process and contributes to creating administration whose usefulness to the end customer is unclear. Let us look at two principal development scenarios. We can call the one horizontal development and the other vertical development.

In the first scenario (horizontal development) groups of actors, e.g. trade organisations, and professional groups, e.g. union organisations, strengthen their respective roles. These groups act to introduce new kinds of training, new systems, new models, new plans, new documents, new roles etc. for the purpose of improving things for their members. The focus is thus on increasing support processes. The effect of this is partly that the number of non-value-increasing activities grows and partly – which is important – that it contributes to concealing the main process of the building project.

The second scenario (vertical development) means that actors together try to strengthen the value-adding main process and make it more effective. Partnering is a recent example of vertical development, often between the client and the building contractor. The effect of this is aimed to be a simplification of the communication and knowledge transferral between the actors and that the unnecessary support processes become visible and can be eliminated.

Our understanding is that there are many good examples of vertical development according to the second scenario. However, in our judgement, horizontal development according to the first scenario has been strongest in the past decades. This development thus contributes in our view to successively increasing the amount of waste and consequently represents our fourth obstacle to sound development.

9 Conclusions and recommendations

Conclusions – immense potential for improvement

This study made an inventory of waste in building projects. The purpose is to stimulate the ongoing debate about building costs by giving examples of things that are done unnecessarily from the perspective of the customer. We made inventories within areas that the building sector's actors themselves chose. Data were collected in direct observations, interviews, group discussions and studies of project documentation.

The inventory shows that there is a sweeping amount of waste – at least in the order of 30 – 35% of a project's production cost, although with a certain variation between projects. The greatest proportion of the waste is hidden to the majority of actors. It is thus important to make as much of this waste as possible visible. Here we have chosen for practical reasons to classify the waste into four main groups.

- *Defects and checks.* An obvious group of waste is defects and their consequences, i.e. defect costs. The hidden cost of defects is greater than the visible cost. Because defects exist, organisations create checks in order to discover them in time and insure themselves in order to spread the risk in the case they occur. Theft and destruction of property are "defects" carried out by unauthorised persons and are thus included in this group. Our estimation is that waste in this group represents more than 10% of a project's production cost.

- *Use of resources.* The second group of waste has to do with how the three resources of work time, machinery and building materials are used. The inventories show a surprisingly large portion of waste in the form of wait times, machinery that is not in use and material wastage. We judge this waste to correspond to more than 10% of a project's production cost.

- *Health and safety.* Waste associated with work-related injuries and illnesses is so large that we chose to report it as a separate group. The projects (the companies) have direct costs for health and safety. The largest cost is for rehabilitation and early retirements, however, and this burden projects indirectly via taxes. Waste in this group represents about 12% of a project's production cost.

- *Systems and structures.* The fourth group is waste in management systems among federal authorities, companies and projects and in organisational structures, e.g. in the branch, in companies and in projects. There is a tendency for improvement work to lead to more and more cumbersome management systems. The types of waste reported in earlier sections correspond together to about 5% of a project's production cost. However, we estimate that this group of waste is the one most underestimated in our inventory.

Reducing waste has to do with freeing up time and resources by working smarter – not necessary faster – and simplifying processes.

Our inventory does not report all waste that is a burden to the customer. The greater part of the inventory is limited to weaknesses. We have also chosen to apply the definition of waste cautiously. Against that background we suggest that the building sector take a common vision to reduce production costs in the long run by half! We find support for this suggestion in several of our separate inventories, where we see that the work that adds value is considerably less than half of the possible work. A realistic long-

term goal is a reduction by one third of the production cost with current work methods. Improvements in certain types of products can probably be greater with other work methods.

At this time we are experiencing a great development in technology, in purchasing processes and in industrialised construction. Leaders of companies claim in trade newspapers that they can reduce building costs by 20 – 30% by better purchasing and more industrialised construction. This offers further support for our proposal.

Recommendations – call for a new approach

Our major purpose has been to make an inventory of waste in building projects. Reducing waste in an effective way requires well prepared proposals for countermeasures. We wish however to point to some possible main directions for the works to decrease waste.

Focus the key process of the project on the needs of the client
A noted leader in industry often spoke during his professional career about the importance of concentrating on the main principle. The building process seems to contain far too many blind alleys. Our first recommendation is thus to further develop methods and skills for identifying the needs of the customer, articulated needs and needs not articulated, as well as methods and skills to check on these needs and keep them uppermost in mind. A stronger focus on the customer's needs makes it possible to more easily see the activities that do not lead to satisfying the needs and to eliminate those activities. Above we called this vertical development. Long-term customer-supplier relations facilitate vertical development.

Train and motivate each employee – leadership as a motor
Waste exists in all activities and processes. Every individual employee knows his own processes best. The greatest and most sustainable force toward improvement lies in the insight and understanding of every employee as to what value the processes he or she uses offers the customer and in employees' desire to actively cooperate to reducing the occurrence of waste. Our second recommendation is thus to create this kind of insight and this kind of involvement in *all* employees, white collar workers and skilled workers alike, so that they successively work to eliminate everyday waste in their own work processes. It takes time to make sustainable changes and requires a well developed and strong leadership. Leadership is thus an important motor for achieving this real change.

As said, creating insight about what is value and what is waste takes time. We thus propose a series of regular meetings to achieve a successive change in viewpoint.

Focus on production
The greatest proportion of resources is used in manufacture, in factories and at the construction site. Our third recommendation is thus to focus especially on eliminating waste in these places. We have not made an inventory of how well resources are used in factories, but it is certain that a great deal of the increase in value takes place there. Our inventory of the use of resources at the construction site shows that a surprisingly small part of resources are used to increase the value of the product. It has to do here with reviewing the planning aids that are used and increasing employees' knowledge and competence in production planning. Production management should also consider how the 168 hours available each week can be used most suitably.

Using the help of federal authorities

A part of the waste is found in the actions of federal authorities. In several cases waste burdens all projects – and thus their customers – equally. For this reason, small changes at federal authorities can in total give a large effect. In national improvement work many actors want the federal government to take the initiative and stimulate other actors to action. For these two reasons, we direct our fourth recommendation to authorities and suggest that they work together to identify – let us say 100 – examples of activities, documents, reports etc. that they themselves create or that they require others to create and that do not (in the situation of today) add any value for the end customer of the building project. To become a good example, this list should be made public and activities be crossed out as they are removed.

Final reflections

When the weekly trade magazine Byggindustrin published our vision in June of 2005 we received a number of extremely differing comments. At one construction site, the site management questioned the seriousness of the journal after having written an article about it at all. The most common comment made by younger company leaders were the opposite, e.g. "yes, I also think that we can cut production costs in half…" and "that's what we're working toward!" Both these extremities strengthen our belief in the reasonableness of our vision. But to get there, it is necessary that all professional groups share the same insight about what possibilities there are for improvement.

The greatest challenge is in creating this insight in each and every person that works in the project, i.e. in starting to see activities, documents etc. in a new way and questioning the way in which each activity leads to greater value in the product or service. During the study we could clearly see how the participants of the project group – as we ourselves – successively changed the way we saw activities and behaviours. Changing viewpoints takes time and requires concrete examples. The latter can be illustrated with the following words at two of our final group discussions.

> *"When you see all the documents, all the meetings…Who carries the wood and who drives in the nails?"*
>
> *"When I see these figures I'm ready to change my opinion."*

Costs could be defined in many ways. Let us look at the example of international purchasing. There is a current trend of clients and contractors purchasing material from Eastern Europe and Asia in order to reduce costs. It is obvious that the prices are lower, the processes are not necessarily more effective. That is because the resources are cheaper. The waste are, in our viewpoints, increased.

As we continue our development work it is thus necessary to make new inventories to clarify actual conditions and move the debate forward. We also have to seriously question current work methods and routines, e.g.

- There is a lack of housing in our large cities. Why does it have to take between two and five years to develop new land use plans when the total (!) work among authorities, architects and others is considerably smaller?
- Why do as many as ten companies make a calculation for the same building project – and sometimes twice – when only one company is going to do the work?

- Contractors often complain that there is too little space at the construction site. Why is 100% of the work force at the site during 24% of the time calculated over all the hours of the week? The site is empty 76% of the time!
- There are frequent discussions about the importance of waste separation at the construction site. But why does the waste have to be transported via the construction site in the first place?

We are often asked how Sweden places itself in an international perspective in terms of amounts of waste. We can not give a trustworthy answer. However, we believe that it can be valuable to make comparative inventories with building projects in other countries in order to find smarter ways to work. The most successful strategy however should be to focus primarily on reducing waste in our own processes.

In conclusion, we wish to remind the reader that we propose in this report that the construction sector takes a common, long-term vision to cut production costs in half. This is only a vision and is intended to contribute to changing our way of looking at different types of work and the way we work. At the same time, however, we can see in several of our sub-studies that the obvious goal in individual sub-processes would be to cut either costs or time in half.

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This report gives the results of an inventory of waste in construction projects. The purpose is to stimulate the ongoing debate on construction costs by giving examples of things that are done unnecessarily, that is, activities that do not offer any value to the customer. The inventory shows that there is waste in the order of 30-35% of a project's production cost.

The report gives examples of waste and obstacles to development. A common vision is proposed for the entire construction sector for cutting production costs in half in the long run. Federal authorities are encouraged to act as a good example by openly reporting how they eliminate waste.

All examples presented are from construction projects in Sweden or from other sources concerning Sweden and its systems and cultures. However, the main message is still relevant for most organisations irrespective which country and culture it has its businesses in.