A Planning System For the End-of-Life Management of Buildings

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Summary

In this contribution, a planning system for end-of life management of buildings is presented. To anticipate an end-of-life management, which will cover deconstruction and rehabilitation measures, numerous different objectives in environmental, technical and economic means have to be taken into account. Thus, alternative scenarios for the end-of-life treatment are considered on strategic, on tactical, and on operational level. Objectives in lifetime-oriented planning are modeled using extended time-based or cost-based objective functions, whereas different alternatives to meet certain targets in the field of sustainability are modeled by using multiple modes. Mathematically speaking, sophisticated optimization models realize both aspects. These models comprise specialized planning methods that can also consider limited financal or technical resources and therefore allow calculating enhanced solutions for numerous different conditions in lifetime management. Case studies illustrate the application of the approach.

1. Introduction

In future, decision-making in lifetime management of buildings will not only focus on the genuine aim of profitability but will also have to meet criteria of sustainability, e.g. limiting the discharge of pollutants into the environment over the whole life-cycle of buildings. The latter can be supported by applying material flow management, which has been proven as a suitable approach to meet prerequisites for a sustainable development in the construction industry. Material flow management covers the entire value chain of quarrying, production and transport of building materials as well as the construction process itself, followed by the use of buildings and finally their deconstruction and recycling. However, the rapid development of ideas for the end-of-life treatment of complete buildings or components has resulted in only few planning systems for the final phase of the building life cycle so far.

2. Case studies of the deconstruction of buildings in Germany and France

In recent years, several case studies about deconstruction have been carried out in Germany and France (cf. [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20]). Nevertheless, only few studies are well documented. An overview about different deconstruction studies can be found in [21, 22]. A comparison between these studies is impeded not only because of the heterogeneity of the documentation, but also the scope of the projects and the different conditions. In fact, the same aspects in the studies are not addressed in the same way (e.g. costs, recycling rates etc.). As a consequence, results have to be compared with great care.

For the evaluation of different dismantling techniques and the determination of the resulting dismantling times and costs, the French-German Institute for Environmental Research (DFIU) launched several projects in Germany and France. During the first project in Germany [5, 6], a timber-framed building located in the black forest was completely dismantled and more than 94 % of all the materials could be recycled.

In order to compare deconstruction with demolition in practice, a project has been carried out in Mulhouse (France), that was especially focused on this comparison [2, 7, 23]. The buildings were divided into two parts, of which one was demolished (using a backhoe) and the other was dismantled (cf. Fig. 1). The location of the building near to the Swiss and German border also allowed the analysis of the possibilities of recycling of materials on an international level.

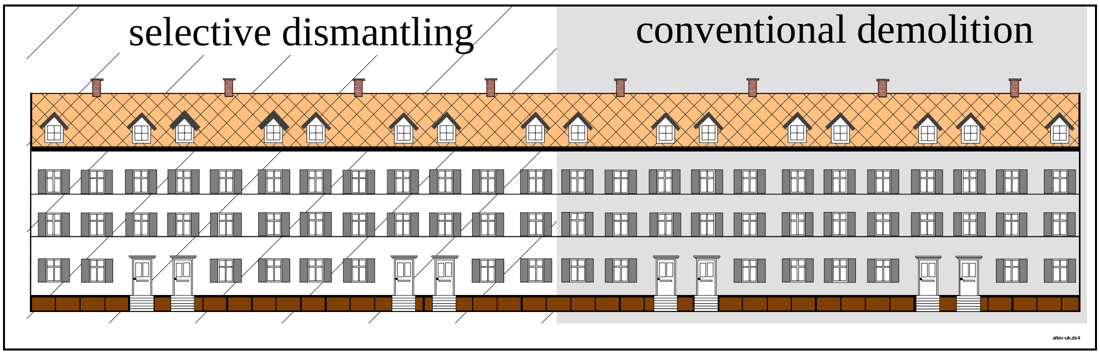

Fig. 1 Dismantled and demolished buildings in Mulhouse

During these projects detailed data on the composition of the dismantled buildings, the duration of the dismantling and demolition activities, the associated dismantling costs and on the recycling options were collected and analysed. Results show that dismantling can already be an economical solution, depending on the type of the building, the recycling options available and the prices charged for mixed and sorted demolition materials. The costs for deconstruction were in some cases lower than those of demolition. Nevertheless, due to different types of buildings, different disposal fees and different transportation distances, costs for dismantling and recycling show tremendous variations, so there is a strong need for sophisticated planning approaches.

3. Deconstruction planning

The aim of efficient deconstruction is to reduce the whole duration for dismantling on the site, to lower the costs, to improve the working conditions and to assure the required quality of the materials. In order to optimise deconstruction, a methodology for the deconstruction and recycling management for buildings has been developed at the French-German Institute for Environmental Research, which is explained in the following. In order to facilitate the task described, a sophisticated computer aided dismantling and recycling planning system is used [24, 25, 21]. The methodology for optimization is based on resource-constrained project scheduling, described in detail in [21, 26, 27]. The structure of this system is illustrated in Fig. 2.

3.1 Audit of Buildings

An essential step both for deconstruction planning and for the quality assurance of materials that are encountered as a result of demolition is a proper pre-deconstruction survey, also called building audit [28]. Although it is not absolutely certain what will be found when structures are broken open during dismantling of demolition, carrying out such a building audit can reduce much uncertainty. The building audit mainly consists of making a detailed description of the building and identifying materials. Based on the documents of the building (construction plans, descriptions, history) detailed data on the composition of the building has to be collected and analysed. Due to the fact that deconstruction normally affects older buildings, reliable information documenting the current state is rarely available. During this audit indications of substances contained in the building, which may influence the quality of the materials must be collected and analysed. The audit also gives precise information for further investigation on possible pollutant sources and contamination of the building.

The planning system supports the audit by the preparation of bills of materials, which contain details of the materials and the locations of building elements and pollutant sources. The content of pollutants can be addressed by a methodology using so-called pollutant vectors for materials and surfaces [29].

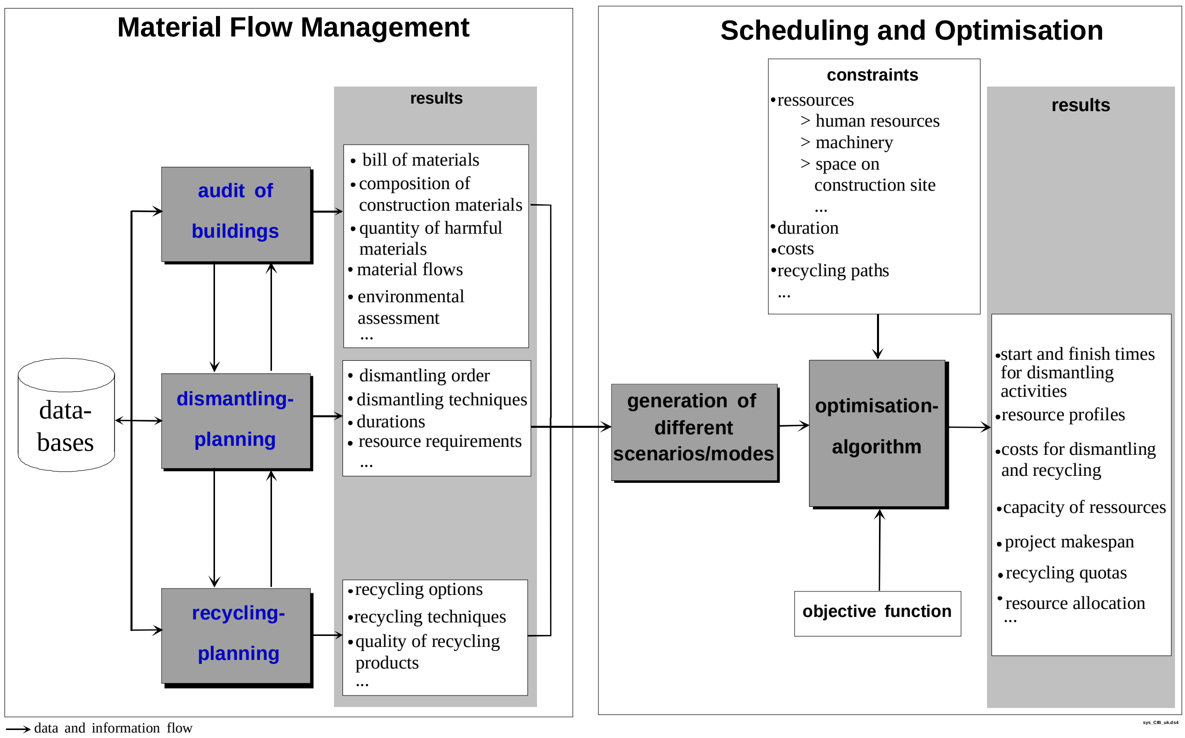

Fig. 2 Structure of the deconstruction planning system

3.2 Dismantling Planning

With the available information about the composition of the building combined with the information about the regional framework for waste management, the planning of the dismantling work can be carried out.

On the basis of the bill of materials, appropriate dismantling techniques are selected and aggregated to dismantling activities. Information about dismantling techniques and corresponding costs can be found in [21, 30]. The configuration of the dismantling activities comprises the determination of the corresponding construction elements (found in the bill of materials) and the selection of the resources necessary. Since the aim of the dismantling planning can be dismantling with minimal costs, dismantling with the aim of preserving building elements intact for later re-use, or dismantling due to technical restrictions etc., the determination of dismantling activities may vary considerably. The computer-supported configuration of a dismantling activity is illustrated in Fig. 3 [31]. For the temporal planning of the dismantling work reference numbers, stored in a database, can be chosen for each construction element depending on the dismantling techniques available.

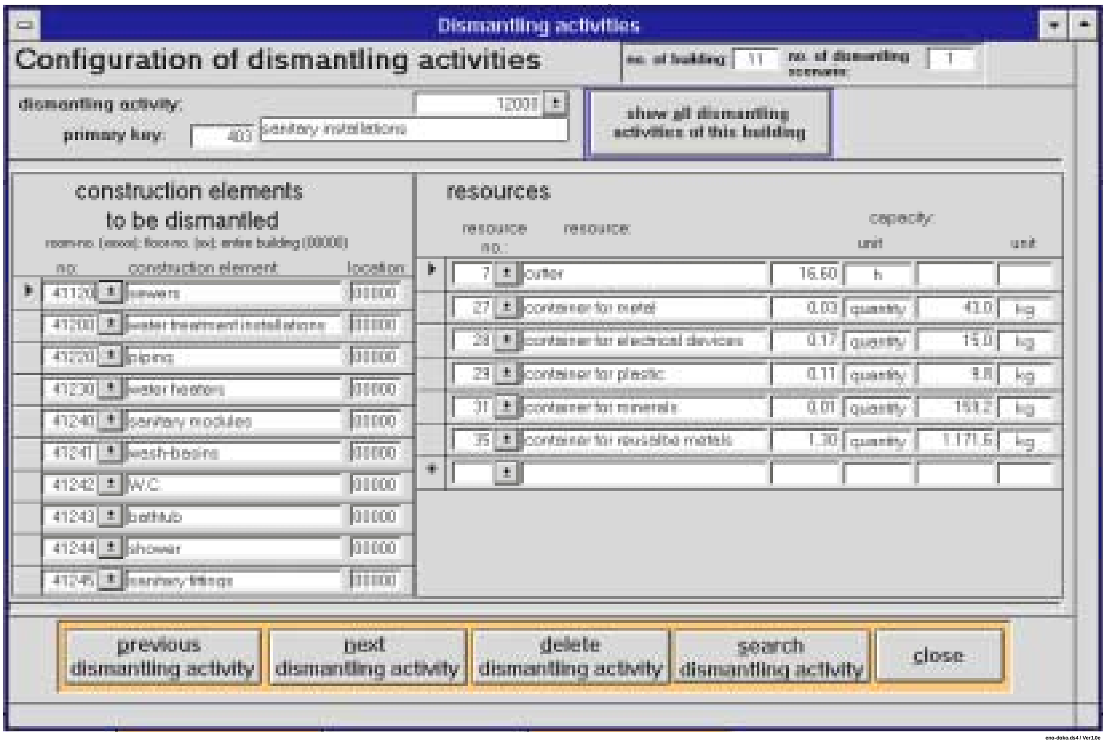

Fig. 3 Configuration of dismantling activities [21]

The dismantling order respecting technological relations as well as security aspects and environmental requirements (like the decontamination of buildings) can be illustrated in so called dismantling networks. Fig. 4 gives an example of a dismantling network for a residential building [29].

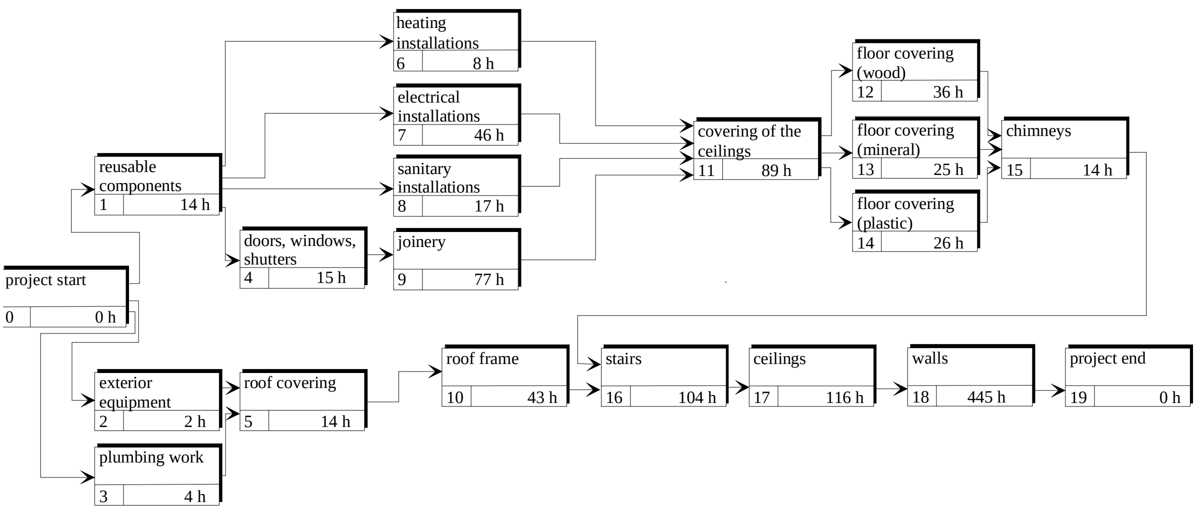

Fig. 4 Dismantling-network for a residential building

After determining the dismantling activities and precedence relations the target of dismantling planning is to find feasible or “optimal“ working schedules. If resources (machines, workers, space on the construction site, budget) are limited this problem becomes extremely complex.

3.3 Recycling and Reuse Planning

The objective of recycling planning is the design of optimal recycling techniques for processing dismantled materials and building components into reusable materials. Depending on the stage of dismantling, the feed can be either a single material or a mix of all building materials. For certain individual materials such as metals, glass and minerals or plastics, recycling techniques already exist. In this case recycling planning is a simple co-ordination. Recycling is difficult, when materials are mixed, when composite materials occur or when pollutants like hydrocarbons or asbestos are present. In order to obtain materials in an optimal composition for recycling facilities, the available recycling techniques as well as the location of processing facilities (see above) have to be considered during dismantling planning. Case studies have shown, that direct re-use of elements can be a promising alternative if dismantling is planned well (cf. [1, 2, 3, 4]).

4. Optimization of deconstruction works

The projects carried out in practice and analysed so far have shown a potential for further improvements concerning cost reduction as well as environmental benefits. Based on these results, computer simulation helps to reveal improvement potentials for deconstruction. In order to show some possible improvements, various simulations and optimisations using the planning tool described above were carried out. Due to this high complexity of the dismantling and recycling planning a sophisticated mathematical optimisation model is used as decision support. The model takes into account the interrelations between material flow management (concerning dismantling and recycling) and project management. The consideration of both, material as well as monetary flows during the various planning stages enables the elaboration of time and cost efficient as well as environmental friendly deconstruction strategies.

In order to evaluate optimal schedules for dismantling different scenarios might be applied, for instance:

- Dismantling of buildings using of the possibilities of parallel work as much as possible,
- dismantling using mainly manual techniques,
- dismantling using partly automated devices and a
- dismantling strategy strictly focused on "optimal" recycling possibilities according to the material flow analysis.

5. Application

Computational results for different deconstruction strategies for a building show considerable economic improvement compared with a deconstruction project in practice. As illustrated in Fig. 5 construction site management can be drastically improved. Optimised dismantling schedules, based on the same framework as in practice, show cost savings up to 50 %. In some cases the dismantling time can be reduced by a factor 2 applying partly automated devices. Furthermore, a recycling rate of more than 97 % can be realised [29, 21].

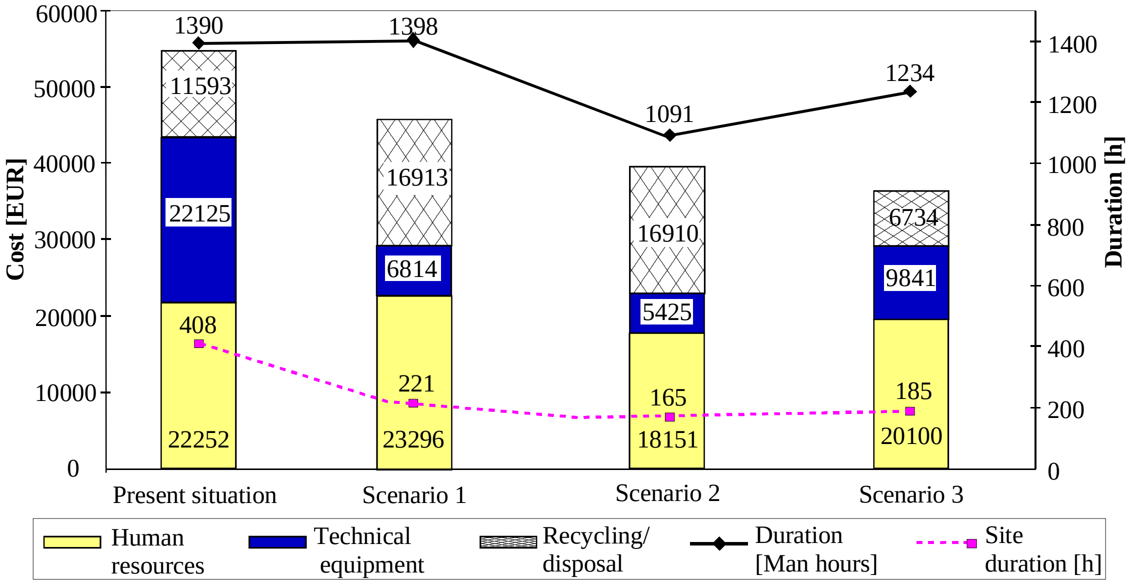

Fig. 5 Cost and duration of different dismantling strategies for a residential building

Based on selected deconstruction strategies the detailed planning and optimisation of deconstruction work can be done. The complete schedules for two different dismantling scenarios (*partly automated* and *material oriented*) and the corresponding project costs indicate that an environmental oriented dismantling strategy imposes a higher effort to the dismantling work. That is, more jobs have to be carried out in order to avoid a mix of hazardous and non-hazardous materials. Nevertheless, environmental oriented dismantling strategies are not necessarily disadvantageous from an economic point of view, if disposal fees are graded according to the degree of mixed materials.

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