DECOMMISSIONING OF NUCLEAR POWER PLANTS – CAN LEAN METHODS HELP TO IMPROVE THE HIGHLY COMPLEX DESIGN AND PLANNING PROCESSES?

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ABSTRACT

In recent years, principles of Lean Management were implemented in a growing number of construction projects with good results in improving of performance. Decommissioning of nuclear power plants requires setting up of a complex process and designing of specialized methods and machines. In this sense it is even more complex than large construction projects. Due to the many laws and regulations (especially concerning safety), decommissioning suffers from time and budget overruns. Therefore, the authors investigated the possibilities of applying Lean Construction methods and tools in the design, permitting, licensing and planning of the decommissioning of nuclear power plants and related facilities. Framework conditions for the implementation are numerous atomic laws and regulations.

The research is based on the following hypotheses:

- The existing system suffers from time delays and budget overruns; it is not only possible but necessary to improve cooperation and results through applying Lean Management methods.
- In the process of executing the first steps of applying Lean, it is possible to overcome obstacles, existing with various stakeholders, for example the fear of losing the independent status of the experts.

Evaluating current state of the art led to first steps, such as lowering batch sizes and creating a continuous flow of information and results of design and planning. The research is based on the cooperation with a variety of sources including owner, engineering firms, contractors, experts, ministries and other regulatory agencies. Difficulties and barriers for implementation are discussed, especially ensuring high safety standards while using cooperative methods for project delivery. Recommendations for further implementation and research, especially to fully validate the second hypotheses, will conclude the paper.

KEY WORDS

Lean methods, decommissioning, licensing, stakeholder, cooperation

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INTRODUCTION

The origin of Lean Management can be traced to the manufacturing industry. With aim to create value without waste the philosophy was transferred to several other branches of industry, examples are administration, banking and construction. In recent years, principles of Lean Management were implemented in a growing number of construction projects with good results in improving of performance.

Decommissioning of nuclear facilities, nuclear power plants and other related facilities of the uranium fuel cycle, starts with the decision to discontinue operation taken by the operator, or in special cases by the responsible regulatory agency. The facility has now to be removed, aiming at the so-called Greenfield, as the final state. The whole project can be divided into several steps. For example, a nuclear power plant decommissioning project is divided into about five to six subprojects. Every single step needs a license for its execution. Decommissioning is highly complex, as on one hand all requirements for conventional pull down and in addition radiation protection have to be ensured. As usual, typical construction processes have to be planned, optimized and coordinated. In addition, special safety requirements must be observed when working with contaminated and activated material and in the area of contaminated and activated facility. Due to high dose, rates some activities cannot be carried out manually, they must be handled remote-controlled. Remote handling creates extreme challenges for the operating personnel with respect to the handling of machines and equipment. Moreover, the planning of these activities and dealing with uncertainties usually exceeds conventional project management.

Attention must be paid to a variety of laws, regulations and standards in addition to complex construction requirements during decommissioning. This is essential to ensure safety of humans and environment. Due to the high complexity and consideration of numerous laws and regulations affecting safety, decommissioning takes a lot of time and is cost intensive. Decommissioning projects thus are even more complex than large construction projects.

HYPOTHESIS AND RESEARCH METHOD

The research is based on the following hypotheses:

- The existing system suffers from time delays and budget overruns; it is not only possible but necessary to improve cooperation and results through applying Lean Management methods.
- In the process of executing the first steps of applying Lean, it is possible to overcome obstacles, existing with various stakeholders, for example the fear of losing the independent status of the experts.

To verify these hypotheses a literature review was conducted. Additional information was gathered in a case-study. Interviews and observations in the field were main part of the study. The research is based on cooperation with a variety of sources including owner, engineering firms, contractors, experts, ministries and other regulatory agencies. Due to the long duration of decommissioning and its complex project structures this research is related to the licensing process for decommissioning only. Projects under execution were not yet analysed. The second hypotheses could not have been fully validated yet, further research is needed.

BASIC RESEARCH ON CURRENT PRACTISE

A basic research was conducted to determine current state of the art. Laws, regulations and standards were analysed to explore boundary conditions for decommissioning. Afterwards current practise in the licensing procedure and target-orientation of all involved parties were made transparent, in order to be able to deduce first improvements while applying Lean Management to decommissioning.

LEGAL REGULATIONS, LICENSING AND SUPERVISION

In Germany, the Atomic Energy Act regulates the peaceful use of nuclear energy. Paragraph seven defines that construction and operation of nuclear facilities, as well as their final shut down and the following decommissioning require a license. To receive this permission the plant owner has to make an application to the responsible regulatory agency, where the facility was constructed, mostly the Ministry for Environment of the State. Implementation of nuclear laws and regulations may differ from one State to the other. The regulatory agency examines, whether all prerequisites for granting the license, written down in the Atomic Energy Act, are met. That means the agency checks the feasibility of the whole project with regard to the protection goals. The Licensing Procedure Ordinance provides information about documents that have to be submitted, so that the agency is able to verify whether prerequisites have been met. Detailed guidelines affecting the formal requirements of documents are not given. It is to the discretion of the operators to define the composition and degree of details of documents submitted.

At the regulatory agencies, only a limited number of employees are working in the nuclear field. Specific expertise in different technical areas, such as structural engineering, mechanical engineering, electrical and control technology, radiation protection and others, is needed to be able to examine the submitted documents and decide on the granting of licenses for decommissioning. Therefore, it is necessary to call independent experts for review. They are contracted by the regulatory agency with the task of examining the application together with all documents. After examination, they set up a recommendation that helps the authority to decide on the granting of the respective license.

Due to the hazardous potential of nuclear energy, legal rules strictly separate the design and planning of decommissioning, prepared by the facility operator, from the review, performed by the independent experts and the Ministry. The regulatory agency and experts are not allowed to design or plan while examining the documents. In practice, the regulatory agency and the experts only ask questions to receive the missing information. The questions are compiled in the “list of open points”. The operator has to answer these open points. In doing so, it is possible to rework some documents for resubmission and re-review. In several iteration steps, all open questions are clarified for the experts to set up their recommendation. With respect to the experts’ recommendation, the regulatory agency decides on licensing.

Costs of reviewing and for decision making have to be borne by the operator. The experts are paid on a time and material basis, with a fixed hourly rate for their effort.

The licensed documents provide the basis for the subsequent execution phase that is the consistent implementation of the license. A change in license may result from modifications or changes made by the operator. These changes must be examined with regard to their feasibility and safety for humans and environment. Execution

comprises testing of new machines or equipment, procedures and changing of facility parts for intermediate stages of decommissioning. Supervision is defined within the documents for decommissioning. For support, the regulatory agency may call experts. The payment of the regulatory agency and experts follows the same rules as during licensing.

TARGET-ORIENTATION OF INVOLVED PARTIES

Furthermore, the target-orientation of facility operators' employees, regulatory agency and experts were considered.

Basically, the operators' employees working in the area of decommissioning have no direct incentive to deliver projects quickly and cost effectively because their employment ends with the end of decommissioning. With regard to the motivation of employees, there is considerable potential for improvement.

Experts receive payment for their effort of reviewing from the operator. Since safety must not be compromised deadlines and budget targets are not given by the regulatory agency. Payment per time spent is no incentive for a quick reviewing process and project delivery. Delays, in particular, are widely accepted in order to ensure high safety standards and the regulatory agency does not force experts into binding delivery deadlines for intermediate expertises and for the report, summarizing the recommendations.

In general, there are no incentives for a quick delivery of decommissioning projects – neither at the regulatory agency nor with the operators' employees nor with the experts called in. The payment rules for review even imply contrary aims, because experts are not forced to make internal processes more efficient, as long as they are paid on an hourly basis.

RESEARCH ON DURATION TIME AND COSTS OF DECOMMISSIONING

Table 1 shows the results of the investigation of the development of costs and time during execution. The study only included public projects; for private decommissioning projects, no data were provided for evaluation. Considerable time delays and cost overruns were observed in each project. Duration increased by 36 to 75 percent and those projects had not yet been delivered. Substantially higher, from 36 to 170 percent, were the increases in costs. None of the projects had complied with the term defined or kept to the respective budget. The Wuppertal Institute for Climate, Environment and Energy has conducted a similar survey for the new construction of nuclear power plants. The results were the same. Construction and decommissioning are similar with regard to their complicated procedures. Both need a license and execution is supervised by a regulatory agency and experts called in. Legal regulations ensuring safety of humans and environment are the same, too. Auler (2006) reports that changes at the beginning of the decommissioning of a large nuclear power plant cause additional costs of 5 million EUR per month. Summarizing this, first part of the first hypothesis – decommissioning is suffering from time and budget overruns – can be verified.

A study carried out by OECD/NEA (2010) showed the main reasons for time and budget overruns to be consisting in changes in the scope of work, design, regulatory standards and project boundaries, financial considerations, contingency and risk management, methodological differences, knowledge management and license delay.

Table 1: Evaluation of time and budgets for decommissioning projects (KIT 2010, FZK 2001)

Project	WAK[4]	KNK[5]	MZFR[6]
Start of decommissioning	1991	1992	1985
Estimated end of project	2009	2004	2005
Estimated costs	970 m EUR	209 m EUR	229 m EUR (estimation in 2000)
Estimated end of project in 2010	2023	2013	2012
Estimated costs in 2010	2.631 m EUR	315 m EUR	311 m EUR
Increase in duration	74 %	75 %	36 %
Increase in costs	171 %	51 %	35 % (from 2000 to 2010)

Within a case study, during our research, persons involved in the licensing procedure – regulatory agency, operator and experts – were interviewed on current processes. These interviews combined with findings of a literature review on lessons learned from decommissioning provided information and background on time and budget overruns and, therefore, an overview of present potentials for improvement of the licensing procedure.

The results were as follows:

- Formal mistakes in application documents: Typing errors, wrong references, no consistent designations.
- Important existing information gets lost, for example at the interfaces to the subcontractors or engineering firms.
- Information for examining the application documents and setting up experts' recommendation is missing.
- Huge batch sizes: For example, licensing applications consist of 120 documents on the average.
- Waiting time for first statement of experts (five months on the average).
- Late detection of mistakes in documents.
- Lack of agreement on and understanding of methods for detection or software between operator and experts.
- Poor coordination between different parties and departments.
- Existing drawings may be wrong because facilities have undergone numerous changes during their lifetime.

4 WAK (Wiederaufarbeitungsanlage Karlsruhe) Karlsruhe Reprocessing Plant
5 KNK (Kompakter Natriumgekühlter Kernreaktor) Compact Sodium-Cooled Nuclear Reactor
6 MZFR (Mehrzweck Forschungsreaktor) Multi-Purpose Research Reactor

- Licensing documents that are too detailed create obstacles, even for the smallest change in execution. Any change or modification made by the operator causes a new examination to take place.

When setting up documents for application, the operator complies with laws and regulations. These define prerequisites for licensing and provide information for setting up of documents. The operator has gained significant knowledge during operation period of the facilities. He prepares all information which – in his opinion – enables the regulatory agency to examine decommissioning planning and to decide on the granting of the license. The regulatory agency and experts are more familiar with nuclear laws and regulations. Their experience results from projects in the past. On the other hand, the regulatory agency and the experts do not have detailed knowledge of the facility. Provided that the responsible persons have not been replaced, basic knowledge gained during supervision is available.

The present process is characterized by sharp boundaries between the persons and institutions involved. This is working in silos in its most extreme form with the result that the documents compiled require several phases of reworking while the combined knowledge from the parties involved cannot be made use of in a concurrent planning and engineering effort. In other words, it is possible to improve the licensing process by improving the cooperation and concurrent collaboration of all parties.

It is obvious that the Lean Construction principles and methods are the key to new and improved decommissioning licensing procedures. The methodology of target value design can create an additional positive effect where safety must be the highest value. Therefore, and in principle, it is not only possible but necessary to improve cooperation and project results by applying Lean Management methods. Several detailed considerations are given in the following.

HOW LEAN MANAGEMENT COULD IMPROVE DECOMMISSIONING

Unnecessary reworking, for example of documents with formal mistakes such as typing errors, wrong references or non-consistent designations, results from qualitative problems. These can be avoided by using tools and methods that prevent mistakes or by implementing methods that detect such mistakes at an early stage.

In a literature research, application of Lean Management to similar cases and with similar obstacles and problems was investigated. The Facilities Development Department of the Office of Statewide Health Planning and Development (OSHPD), responsible for the approval of all hospital construction, changed its review from an isolated process, similar as described above, into a phased plan review (PPR). The traditional review model started when documents were completed, whereas PPR starts with the outset of the project. Designed project segments are submitted according to a defined schedule. Instead of traditionally reviewing the entire project at the end, OSHPD reviews these segments right after submission. PPR also works with conditional acceptance of segments. Unless there are no changes, they are finally approved. Therefore, the agreement that conditionally accepted segments will not be altered is essential. Collaborative and open communication between the integrated team members are key factors of success (OSHPD 2008).

The following sections concentrate on eliminating waste due to huge batch sizes and the resulting inventories, on possibilities to improve coordination and cooperation and on the potentials of target value design.

LOWERING BATCH SIZE TO CREATE FLOW

According to a survey, 120 documents are as a rule submitted together with the licensing application. On the average, it takes one year to compile all these documents. The entire package is a huge inventory of information. In view of this considerable amount, it is impossible to exclude mistakes. Regulatory agency and experts need a long time to get an overview of the entire project. After five months on the average, the first expert statement is available. During that time, no faults or mistakes are reported. The current system cannot exclude additional after-effects. This contradiction underlines the importance of the Lean principle, i.e. of bringing the parties together at an early stage for creating a common understanding of what the project is all about and for seeking of changes to optimize.

Learning is an important principle in Lean Management. Construction projects have long lead times for their delivery. Therefore, it is not only essential to learn from one project to the next, but also during a project's delivery. This is similar in the case of decommissioning. To implement short learning cycles and obtain positive effects on detected wastes, batch sizes have to be reduced.

Legally, it is possible to divide decommissioning projects into several subprojects for licensing. For examining the feasibility, an overview of the whole project must be provided at all times to ensure that activities within one subproject do not cause disadvantages in executing activities within the next step. Dividing the license into smaller parts, one obtains quick learning cycles and an earlier start of execution. This will create cost and time advantages. At the same time, greater efforts will be required to coordinate the steps and, therefore, costs will rise. It follows, that a continuous subdivision of a project into $n > n_k$ subprojects brings no appreciable advantages. As from a critical number of subdivisions n_k, costs will exceed the benefit. It is not helpful to implement small batch sizes throughout the project.

If the term batch size is set in correlation to the number of documents, a new approach results, namely lowering the batch size of the application meaning the number of documents. With his application the operator sends all documents describing the project, to the regulatory agency. Then, the regulatory agency estimates the extent of the experts' assessment for reviewing and due to this the basis for the contract. Even with a reduced number of application documents, the regulatory agency must be able to decide on the extent of the review. Due to their supervision in the past, the agency has some knowledge of the facility. Thus, it is possible to apply for licensing only by submitting a conceptual design for decommissioning set up during the operation period. Within an iterative process more and more documents, detailing the decommissioning project, are given to the experts for review and recommendation. This iterative process improves fast feedback cycles on the documents.

The principle of flow is very important in Lean Management. Womack et al. (2004) identified it besides value, value creation, pull and perfection as one of five basic principles. The above explained lowering of batch sizes can improve flow or makes it possible in the first place.

IMPROVEMENT OF COORDINATION

To make the above described approach of lowering batch size possible, changes in procedure are necessary. To achieve the objective of receiving the license for

decommissioning, a conceptual design is not sufficient, because the description of the whole process is too imprecise. The conceptual design, therefore, must be converted into a more detailed operational sequence description by adding further documents. The conceptual design covers a rough overview of the decommissioning activities. It is task of the operator to set up documents describing decommissioning more in detail and, hence, to get the license. In current practice, the operator sets up documents for application in an isolated position. Communication with regulatory agency and with experts does not exist. That system should be changed for future decommissioning projects. Operator, regulatory agency and experts could work together in a multidisciplinary team to deliver the joint project. Combined strengths of the operator and reviewing parties will lead to early interactions. Requirements for examining documents and the next process steps will be planned jointly.

Applying low batch sizes, the documents better fulfil the requirements for examination. In addition, transparency regarding further steps will be increased. Then experts and regulatory agency are able to improve their planning activities in relation to other projects.

ADDING POSITIVE ITERATIONS

The improvements described so far are restricted to processes. Improvement of licensing documents and design is not yet included.

Other than in the case of execution, iteration steps are not always negative. Ballard (2000) says that also positive reworking steps exist in design. Negative iterations cause waste, positive iterations will improve design. After lowering batch sizes and improving of coordination and cooperation the implementation of positive iteration steps should be established. To improve positive iterations, information and documents have to be exchanged quickly. A good communication between all involved persons will support this approach.

TARGET VALUE DESIGN

As shown above, the Lean principles of eliminating waste by reducing batch sizes, of bringing the teams together early in order to improve the learning and understanding process and of facilitating positive iteration can and should be applied in the decommissioning of nuclear power plants. Most likely, it is the only way of getting the necessary improvements, since traditional project management has failed to deliver results. The main justification held by all parties involved is that safety cannot be compromised and inefficiencies are the result of the safety principle.

A particularly high potential lies in the application of target value design. Improvement of the activities' efficiencies cannot be achieved by target costing, since processes cannot always be determined in advance and safety is the prevailing value. However, target value design, which has already proven its value in complex situations like design and construction of hospitals, can create a tremendous result in the field of nuclear decommissioning (Lichtig et al. 2009, Ballard 2009). Here, the value of safety must have highest priority. Therefore, in our future research we shall concentrate on going through the present procedures of target value design to detect necessities of changes or additions to make it applicable to and feasible for nuclear decommissioning. Through that, the methodology of target value design could reach a new level, possibly with positive feedback into construction.

DIFFICULTIES AND BARRIERS

To improve decommissioning the cooperation of all parties must be improved. While implementing cooperation some obstacles have to be overcome. The two major obstacles are:

1. Benefit for all parties involved is an important prerequisite of cooperation. Improved cooperation is intended to ensure an economic and quick decommissioning. This is obviously of advantage to the operator. Experts, who are paid on an hourly basis, have no significant advantage through improving cooperation, as their payment results from their effort and is not related to the project result. This means, changing the current system towards an improved cooperation is no significant benefit for them. While advantages for changing do not exist, they have no incentive to change their position within the current system. However, improvements cannot be achieved if experts are not willing to deliver their recommendations quickly to save time and money.

2. Legal regulations of nuclear facilities demand independent reviews for safe decommissioning without hazards for humans and environment. However, this strict separation hinders the parties involved from cooperating and, therefore, is an obstacle to be taken seriously. It would be possible to achieve an improvement of the current system through cooperation, but safety has first priority and is more important than improving current procedures.

Both obstacles are critical and must be overcome if Lean cooperation shall be applied in decommissioning of nuclear facilities. It seems to be relatively easy to overcome the first obstacle. Tender regulations are not a problem since the number of expert firms is so small in that field that contracts and assignments are usually negotiated and not competitively tendered. Within these negotiations, it is possible to come up with a new form of contract that gives incentives that are necessary to enable Lean. In a first practical project, these investigations will be continued in that respect.

The second obstacle is more serious, since it would require a change within the legal regulations. This also means that the government must be convinced that early cooperation and target value design are not a threat to the safety value. Actually, the opposite might be true and the combination of highest safety with more efficient results is not too far-fetched. The second research hypothesis cannot be verified yet. Again, further research is necessary and will be done during the practical project.

CONCLUSION AND OUTLOOK

Due to many laws, regulations and standards, stringent requirements and long durations, decommissioning of nuclear facilities is a highly complex process. Unexplored potentials of improvement and high complexity are the reasons why decommissioning suffers from time and budget overruns. Considering the target orientation of all parties involved has shown that a quick and efficient decommissioning is obviously not the common goal. The payment system of the experts constitutes no incentive for a quick review process. Lowering batch size of the application and improving of coordination and cooperation were determined as first steps to generate positive effects on the licensing procedure. OSHPD’s example of a

phased plan review process and the theoretical opportunity of implementing reduced batch sizes will provide the basis for further research.

During active collaboration of the authors with owner, engineering firms, contractors, experts, ministries and other regulatory agencies to evaluate the current state of the art, the setting up of a practical project was agreed. The project starts with the design of the decommissioning method as the first step of the licensing application. Coordination of owner and contracted engineering firms will be improved during that phase. It is envisaged that the regulatory agency and the experts also join the systematic design process. While implementing Lean methods, the authors expect positive effects on the licensing procedure. These can be the basis for further implementations of Lean Management within decommissioning.

To enhance acceptance, further research is needed and will be carried out during the practical project with regard to the use of cooperative methods for project delivery while ensuring high safety standards at the same time. Conflicts of objectives between independent review, high safety, and cooperation of all parties involved must be put under examination. Perceptions that cooperation would have negative influences on safety must be overcome. Implementing target value design seems to be a suitable method for implementing Lean for the purpose of decommissioning. Setting safety as the targeted value will ensure highest safety standards while at the same time achieving economic advantages with regard to project costs and duration.

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