Progress in Nuclear Energy 99 (2017) 155–164

Contents lists available at ScienceDirect

Progress in Nuclear Energy

journal homepage: www.elsevier.com/locate/pnucene

How benchmarking can support the selection, planning and delivery of nuclear decommissioning projects

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ARTICLE INFO

Article history:
Received 25 August 2016
Received in revised form
14 April 2017
Accepted 3 May 2017
Available online 29 May 2017

Keywords:
Decommissioning
Nuclear legacy
Benchmarking
Methodology
Statistical analysis

ABSTRACT

Nuclear Decommissioning Projects and Programmes (NDPs) are jeopardized by several risks, long schedule and cost estimates that lay in the range of hundreds of billions of pounds. Moreover, in some countries, these estimates keep increasing and key stakeholders have a limited understanding of the determinants that engender this phenomena. Benchmarking refers to the process of comparing projects in order to identify best practices and generate ideas for improvement. However, even if it is the envisaged approach to tackle the decommissioning challenges (and due to the NDPs' uniqueness), until now, benchmarking has been only partially used. This paper proposes an innovative methodology to benchmark decommissioning projects, both from the nuclear and non-nuclear industry, within the UK and worldwide. From this cross-sectorial and cross-country analysis, it is possible to gather a list of key NDPs' characteristic and statistically test their correlation with the project performance. The ultimate aim of the research underpinning this paper is to investigate the possible causation between the NDPs' characteristics and the NDPs' performance and to develop guidelines to improve the selection, planning and delivery of future NDPs.

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1. Introduction

Nuclear decommissioning is a long, expensive and complex process with a multidisciplinary nature (Laraia, 2012a). Its scope is defined by the International Atomic Energy Agency (IAEA) as "*the administrative and technical actions taken to allow the removal of some or all the regulatory controls from a facility, except a repository which is closed and not decommissioned*" (IAEA, 2016a).

However, the scope definition of "nuclear decommissioning" is not internationally agreed, which explains why the translation of this term in different languages is generally inadequate. Laraia (2012a) defines decommissioning as the "*administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a facility and to restore the site to new use*". The World Nuclear Association (WNA, 2015) states that "*the term decommissioning includes all clean-up of radioactivity and progressive dismantling of the plant*" and that "*for practical purposes it includes defueling and removal of coolant*". Conversely, the US Nuclear Regulatory Commission (NRC, 2016) strictly defines the start of nuclear decommissioning "*after the nuclear fuel, coolant and radioactive waste are removed*". The IAEA (2016a) focuses on the end of decommissioning and points out that it "*typically includes dismantling of the facility [...] but this need not to be the case*". In the UK, the Office of Nuclear Regulation (ONR, 2015) provides advice on when to consider operations to cease and decommissioning to start, and considers waste management to be an integral part of decommissioning and dismantling, since (in terms of the process) they cannot be separated, and costs need to be appraised together.

At first sight, this lack of agreement in the definition of "nuclear decommissioning" might seem a mere semantic issue, however, it significantly impacts on the project scope and consequently on the budget and schedule of Nuclear Decommissioning Projects and Programmes (NDPs). For instance, spent fuel (Lawless et al., 2014) and high-level-waste management (Kermisch et al., 2016) have a significant impact on the NDPs' budget. Hence, it is necessary to clarify which is the starting and the ending point of the NDP and to highlight when cost estimates for "nuclear decommissioning" and "waste management" are evaluated together, as in (OECD/NEA, 2012).

Additionally, due to the lack of sufficient data regarding completed NDPs, the difficulty in gaining appropriate information, and the overall NDPs' uniqueness in terms of complexity and

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http://dx.doi.org/10.1016/j.pnucene.2017.05.002
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variety, there is a huge gap in the literature concerning benchmarking of NDPs. Therefore, even if benchmarking is the envisaged approach to tackle the decommissioning challenges, it has only been partially used in the nuclear decommissioning sector.

This paper aims to fill this gap with a methodology based on benchmarking to:

- Establish the criteria to evaluate the performance of NDPs from the project management perspective, according to the different type of NDPs, timescales and stakeholders, as suggested by Turner and Zolin (2012);
- Assess the statistical correlation (and the possible causation) between the NDPs' characteristics and the NDPs' performance;
- Ultimately develop guidelines to improve the project management performance of future NDPs.

The final aim of this research is to gain a critical understanding of the statistical correlation between NDP characteristics and NDP performance in order to develop new knowledge concerning the management of NDPs. This will enable the drafting of empirically-based guidelines and to establish sustainable improvement objectives to support the selection, planning and delivery of future NDPs.

This paper firstly describes the challenges of the decommissioning industry, with a focus on NDPs. Secondly, it investigates the benchmarking analysis applied to the construction industry and explains the case selection. Finally, it presents a deep reflection on the way forward for the adaptation of benchmarking on the nuclear decommissioning industry.

2. Challenges in the delivery of nuclear engineering projects

2.1. Project management challenges in the nuclear industry

At the end of 2015, 439 Nuclear Power Plants (NPPs) were in commercial operation in the world, accounting for a total installed capacity of 380 GWe (IAEA, 2016b). However, despite more than 500 NPPs and a number of other nuclear facilities having been built throughout the 20th century, their construction is still an enormous challenge and their successful completion is still hindered by a number of uncertainties and risks. This causes significant schedule slippage and relevant increase of the original budget (Sovacool et al., 2014; Locatelli and Mancini, 2012; Ruuska et al., 2011; Ross and Staw, 1993).

Conversely, the number of completed NDPs is negligible, being only 16 NPPs and a limited number of other nuclear facilities fully decommissioned in the world (OECD/NEA, 2016). Therefore, the information available to the management regarding past experiences is still limited and fragmented (see the assessment of dismantling steam generators by Hornacek and Necas (2016)), and NDPs' uncertainties can be even higher that the ones of nuclear new build.

2.2. Project management challenges in the nuclear decommissioning industry

Globally, the cost estimates for decommissioning projects lie in the range of hundreds of billions of pounds. In Europe, 77% of the NPPs in shut-down state were located in the UK, France and Germany (Öko-Institut, 2013), and the highest figures are related to the decommissioning of Sellafield (UK), where the total cost reaches £ 53.2 billion (NDA, 2016), accounting for more than half of the decommissioning costs of the nuclear facilities in the entire country. Sellafield is a nuclear fuel reprocessing, waste management and decommissioning site, and it incorporates two First Of A Kind (FOAK) NPPs: the Windscale advanced gas-cooled reactor which is currently undergoing decommissioning and dismantling, and Calder Hall which is awaiting decommissioning and dismantling. In addition, many other facilities on Sellafield site and across the UK are undergoing preparations to be decommissioned. In France, cost estimates for nine reactors to be decommissioned reach more than £ 2.5 billion (CdC, 2012), that represents approximately 43% of their construction costs (Öko-Institut, 2013). In Germany, the decommissioning costs for the Greifswald reactors add up to around £ 0.7 billion (Öko-Institut, 2013).

Moreover, not only are the estimated costs for NDPs very high, but they are also a lot higher than comparable non-nuclear decommissioning projects. This difference is sometimes referred to as “nuclear premium”, as it includes all the additional costs that NDPs have to face which other decommissioning projects do not have to bear. These additional costs are usually related to radiological hazards and safety & security requirements, but also may be due to the fact that people that work in the nuclear industry need to be more focused on quality and therefore might earn more than colleagues in non-nuclear sectors. Indeed, the report by the Oxford Economics (2013, p.48) states: “*Given the focus on quality and skills, it is reasonable to assume that these activities will also command a premium over and above the same activities in non-nuclear sectors*”. According to the Oxford Economics (2013), the nuclear premium ranges between 10% for professional-services-related activities and 20% for manufacturing activities. This exemplifies that NDPs are characterized by high and highly variable costs, long schedule and a range of risks that in many countries are even more significant than the nuclear new build. Also, the average budgets for some of these NDPs keep increasing (NEA/RWM, 2011), and key stakeholders have a limited understanding of why this happens.

NDPs are also hindered by the fact that the number of NPPs that have been fully decommissioned is negligible in comparison with the number of facilities that have been built throughout the last century. This is due to three main reasons:

- Early NPPs were designed for a life of 30 years (WNA, 2015), but several factors such as bad knowledge management, loss of knowledge, NPPs not designed to be decommissioned, and early tendency in preferring the deferred dismantling strategy (e.g. in France) caused the postponement of the beginning of the decommissioning (Laraia, 2012b);
- Newer NPPs have been designed for a life of 40–60 years (WNA, 2015), so the majority of the NPPs installed have not reached the end of their forecasted lifecycle yet;
- Some nuclear facilities have benefited from a lengthening of their operating licence.

Besides, due to the technical variety and complexity of nuclear facilities, NDPs are characterized by unique characteristics, which continuously raise new concern on how to tackle upcoming decommissioning challenges. The NDPs' uniqueness is caused, for instance, by:

- National policies and administrative requirements (OECD/NEA, 2010a);
- The long duration of the project and remote siting of the nuclear facility that created a unique surrounding community that strongly relies on the activities of the nuclear facility itself;
- The fact that: (I) at the end of a NDP, no revenues-generating-assets are created, which is what normally occurs in the presence of capital projects. In fact, the ultimate goal of a NDP is the remediation of a site to brown field or green field suitable for next use, but the end of the NDP is not directly connected to a stream of revenues. Therefore the incentives to conclude the project on time are not driven by any future expected income;

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