DOI:10.21276/sjeat.2017.2.2.2

Saudi Journal of Engineering and Technology
Scholars Middle East Publishers
Dubai, United Arab Emirates
Website: http://scholarsmepub.com/

ISSN 2415-6272 (Print)
ISSN 2415-6264 (Online)

Research Article

Managerial Issues and Implications When Constructing Underground High Level Radioactive Waste Storage Facilities in the UK

P. James
Project Director, Graduate School Bangkok University, Bangkok, Thailand

***Corresponding Author:**
P. James
Email: paul.j@bu.ac.th

Abstract: This is a research paper focused on assessing experienced project managers/senior engineer's perceptions of managing various project issues relating to a proposed underground radioactive waste storage DGF project in the UK. This empirical inquiry utilised an interpretive perspective. The scope for this research were project managers/senior engineers who were registered Chartered Engineers and experienced in managing deep civil engineering projects. The discrete population for this study was made up of individual managers/senior engineer's (19) presently located on multiple, independent sites, and a total of 11 managers/senior engineers were determined as the resultant sample frame. The outcomes consisted of six (6) main themes, namely: Managerial, Technical Capability, Process, Costs, Project Administration, and Environmental Issues; and twenty (20) sub-themes raised from a literature embedded question. Very little management research, if any, has been conducted in this extremely provocative area and the paper exposes profound concerns relating to aspects of the management, which is academically unexplored in today's demanding international nuclear civil engineering environment.
Keywords: Management; Nuclear; Storage; Civil Engineering; UK.

INTRODUCTION

The UK government intends, through the Nuclear Decommissioning Authority [1], to construct and operate a deep geological storage facility (DGF) in the UK for high-level nuclear waste (HLW). In England, this is planned to cost £3.8Bn [2], with an anticipated total operating cost of £11.5Bn for the next century - but only for NDA costs - other costs will be paid by the taxpayer under the UK Government's National Infrastructure Plan (3; based on a software model created by MWH [4]. For example, to include legacy waste would make the cost £14.3Bn as calculated in 2008 [3]. In September 2012, this was increased to £15.4Bn by the HM-Treasury. Further, this facility was to provide storage for 470000m^3 of intermediate level waste (ILW) and 1150m^3 high level waste (HLW) - although other estimates suggest the need for only 290000m^3 of ILW and 1260m^3 of HLW [4-6]. The official figures [7] indicate a total of 1770m^3 HLW and 95600m^3 of ILW, which is substantially different to other government estimates. Further, the DGF location process is marred by controversy, delays and perhaps deliberate political ambiguity (such as 8; and [9]). Most researchers in this specific area target the politics of managing radioactive waste [10,11] thus underscoring a need to provide some illumination on the variety of intense managerial issues directly related to such a venture - especially as at least 15 countries worldwide have been actively looking for a similar location within their own geological boundaries [12].

Radioactive waste is considered to evolve into a number of specific classes [13]. The three classes are High-Level Waste (HLW), Intermediate-Level Waste (ILW), and Low-Level Waste (LLW). However, the IAEA configures six levels [14] - which the UK system needs to take cognisance of, as signatory member to the IAEA, although it is demonstrably ignored by the UK RWM (Radioactive Waste Management). The NFLA [15], however, determines that this is part of the "conspiracy". associated with the DGF project. This is because nuclear waste could be transported wider, have more transport operations, and be stored on multiple sites more often. The NDA denotes that operating around the 3-classes [16] can mean …"*a more effective strategy*"… utilising a …"*balance of priorities*", thus putting nuclear waste in locations that are more appropriate for the NDA - …"*where wastes are managed based on their best means of disposal rather than what waste category they fall into*…" [17] - rather than meeting local population nuclear environmental concerns.

The storage of various levels of nuclear radioactive waste underground has been done intermittently through trials over the past 60 years in the UK [18] - but never ILW or HLW. The final report of CoRWM 2006 indicated conclusively that 33% of the UK was suitable for the position and location of a deep geological waste repository. However, experience since has suggested quite clearly that it is very difficult to exploit and consistently shows numerous structural, security, social, environmental, management and financial impediments for it to succeed. For example, the Cumbria CC acceptance in 1996 and rejection in January 2013 [19], was but one of the outcomes of such a misguided position. Moreover, after 60 years of nuclear waste creation, there is no viable, deep disposal site anywhere in the world [20]. However, this paper focuses on the civil engineering - structural, technical and managerial aspects of the proposed underground storage project.

LITERATURE REVIEW

The UK government refers to such radioactive waste storage as geological disposal (Deep Geological Facility - DGF), which appears to be a political statement and thus taking the focus away from radioactive-waste disposal [1]. Further, the search for a suitable geological location for a depository has been on-going since 1976 [21], which also illustrates the difficulty and the critical need to find a suitable location(s). This screening process which is fundamentally desk-based [22, 23], has raised a number of key issues which is led by geologists for what is essentially going to be a developed mine for the specific purpose of storing HL radioactive waste. This assessment would appear to be flawed by using - geologists - rather than being led by mining and nuclear engineers. No mining concern in the UK can be assessed and developed without mining engineers. However, for the storage facility, the specific use of only using geologists in a desk-based project [22, 23] indicate a lack of awareness of mining issues and an over-imposed political notion that the problem of burying HLW is a geological one. The DGF assessment process was stated as voluntary, until a law was passed in 2014 [1], making the central government the decider for where it will be imposed at some stage, on a community - even though the government is offering upto £40m for the privilege of locating the disposal facility. Again, this has caused great consternation throughout the UK.

This concern that the lead has been taken by the British Geological Survey to screen "*areas covered by expressions of interest*" [22], rather than mining engineers, nuclear physicists or nuclear engineers has been noted elsewhere. Further, from a safety perspective, it is assumed that current mining and HSE legislation relating to mine construction will apply. It is posited that the determination of the facility as a mine is carried out by virtue of the Mines Regulations [24], rather than the Nuclear Installations Regulations 1965 (s3(b)(f)). However, this determination will need to be tested when the site is finally located and needs to be licensed [25].

The need for such underground HLW storage facilities

Most of the radioactive waste in the UK is stored at present at Sellafield, with other facilities located elsewhere in England, Wales and Scotland. However, this is considered a non-option by Alexander and McKinley [26]. Hence, the need to find other alternatives means for storage. The UK government determined that "underground storage" is the best strategy for radioactive waste disposal (1, s3.5, p20), which corresponds with 6 other nations (ibid, s3.10, p20); situated at one site only (ibid, s3.18, p24) where the radioactive waste will be disposed of (ibid, s3.21, p24) meaning sealed and abandoned. Little has been reported about the state of the present "high risk" situation [27] where all-available nuclear waste is stored at Sellafield for the last 50 years [6], and whether the dilapidated state caused by mismanagement [27] has prompted the UK government to take measures to reduce its over-capacity. For example, the new facilities built for surface storage of ILW at Berkeley [28]. Further, responsibilities have been devolved to individual states in the UK, [1] making the situation and further progress very unclear. So the real focus for the UK government is now only on England.

The planned geological disposal facility will "*isolate and contain the radioactivity for a very long period, thus preventing any harmful amounts of radioactivity being released into the environment in the future*." (1, s3.7, p20). This gives rise as to the impact of environmental issues and since so few examples of such a disposal has been developed, how does the UK government know this strategy is safe? For example, what will be the safety characteristics of the work method to protect workers and the environment while the DGF is in operation [29] - as required by the HSWA 1974, the Energy Act 2013 and the Nuclear Installations Regulations 1965. This is especially important given the latest disastrous underground storage experience in the US [30].

The UK government's case is solely based on a 1984 report to a Paris conference [31] and updated by a report in 2014 [32]. Further, the baseline inventory is accepted as that contained in RWI [7], which when it is considered that it is 12 years old, it is grossly out of date – even if it has been updated by other reports in 2007 and 2010 [33]. It would appear that there is a secretive component attached to how much of the radioactive waste is stored, where and how much - and further how long this waste is going to be temporarily stored above ground - giving rise to speculation as to when the deep storage facility will need to become operational. The NDA indicates that the first - and probably only - underground facility will be in operation from 2040 until 2140 [34,35] but this has now changed due to the pull-out of Cumbria Country Council. To-date little progress has been made on the new site selection, which is stated to restart in 2017.

The only successful deep geological storage facility that exists today is a test facility in France [36] where no HLW is stored. However, on the same site there is now a specific project for HLW (Cigeo) located in Meuse/Haute-Marne [37]. This site, licensed in 2015, is expected to open full-storage operations in 2025 [38]. This was secured by approvals from the local community and also through good coordination work between the developer and the community [39].

The method of storage development

Storing radioactive waste underground is not new in the UK. For example, Dounreay has new underground vaults, storing 175000m^3 of LLW, which has been continually in operation since 1959 [28,40]. A new HLW surface storage facility will be in operation at the site presumably from end of 2016 [41]. However, no underground facility has yet been developed or in any form of trials for the storage of HLW. Further, the UK government has mandated that all HLW would be stored above ground for 50 years prior to any permanent storage underground. This is different to other countries such as The Netherlands, who intends to store HLW for 100 years prior to a DGF build [42] presumably because of the continuing exothermic reaction for each HLW parcel - the WIPP experience indicates why the Netherlands is perhaps a little more enthusiastic about their plans for surface storage. Consequently, the risks associated with such a construction and venture is very serious. Overseas, for example Finland, where plans are well developed to store HLW below ground starting in 2025 at Onkalo [43, 44]. Whilst the method for packaging HLW using vitreous, stainless steel shelled matrix/modular pods has been developed and is now widely accepted internationally [45, 46], none of which have been tested in underground settings of any kind. Therefore, the first time a HLW site goes live, will be the first time such pods are tested. Is this really the way forward? Consequently, there remains a dearth of evidence of research on the successful method of storage and/or the effects of the underground environment on the stored material, its containers and the underground space itself [30]. This is an obvious concern for burying HLW underground in the UK. When assessed from an engineering perspective, the Onkalo site appears to be using unfinished tunnel surfaces, which does not provide adequate protection for the long-term worker at the site. Further, there is no research that shows clearly the way forward for the construction parameters of the underground spaces. This also brings to the fore the notion whether geologists are the best-fit professionals to advise on underground development and its management. Leakage is still an issue, as the French research indicates clearly that eventually the radioactive “iodide and chloride anions” will “diffuse to the surface” [39]. Further, their underground evaluation began in 1999 [36] and with 17 years of experience of such experimentation and assessment are still not positioned to determine how best to move forward. So this begs the question, how can the UK authorities move to an underground location without first determining the methods of construction and storage?

One of the main flaws of the UK government DGF strategy is that it has not carried out any deep mine trials of storage methodologies, nor utilised any materials or packages similar to HLW containers in deep mine settings for research purposes. In this respect, no designs have been released to illustrate how such materials will be stored, nor how the insitu vaults will be secured nor how the tunnel connections will sectioned-off to prevent discharge between sections. Further there is no indication of the lining requirements of storage places or connections and what materials would be utilised. This is all the more difficult, as the parameters of the actual HLW materials are unknown, where it is assumed that designs to encompass them will be developed or copied from those presently developed - again, it would seem, without appropriate testing. Further, the ONR (Office of Nuclear Regulation) has the duty to regulate licensed nuclear waste management sites, but since the DGF has never been part of the nuclear waste-management system previously, it offers to them something that it has not been seen before. It therefore raises the question of licensing and regulation of an entity that it wasn’t designed or mandated to regulate and therefore raises the issue of regulatory independency and competence [30] and is contrary to their operating mandate as determined in their updated guidelines in 2016 [47].

Industry Costs

It would be more of an effective assessment if life-cycle costs associated with other industries were taken into account. The main comparison is with coal mining, which could have provided deep mine storage of such nuclear waste, but were entirely ignored. Legacy costs of closing mines came to about £1.75Bn.

This is cheap when compared to the legacy cost of waste treatment alone – estimates today as (Sellafield only) without the added cost of a DGF facility costing a minimum of £16Bn by 2125, and which is likely to increase to well over £100Bn+ within 100 years (the minimum life-time of the storage facility) - although estimates by the NDA suggest the cost is likely to be only £12Bn [17]. This does not take into account the cost of new build nuclear facilities – estimated to be at £232Bn by 2100. In essence, the politics of a DGF have not really been explored, and Maggie Thatcher's notion that electricity costs to the user as being cheaper to close the coal industry was absurdly untrue, enigmatic and was obviously politically staged, raising the issue of the lost "access to deep storage facilities" by closing all coalmines in the UK.

Consequently, this paper may help with illuminating the substantial management issues surrounding the build of a geological disposal facility (DGF) in the UK. Having raised this as a literature gap issue [48, 49], this creates the context for the research question, *What are the management issues relating to locating, building and operating a deep geological facility for the storage of HL radioactive waste in the UK*?

METHODOLOGY

Within in this engineering context, a more engaged approach was considered crucial and appropriate which ultimately required an informed personal sharing of experiences on such raised issues. This empirical inquiry therefore utilised a focused interpretive approach [50, 51]. Using a qualitative process provides a way to assess the construction and storage issues based on individual appraisals relating to ongoing experiences and is wholly applicable for generating this kind of empirical data. This research focused on the perceptions of senior managerial experiences, gained through more than 10 years of direct site management in complex engineering projects similar to contemplating or preparing to implement deep geological storage of high-level radioactive waste in the UK and who were also Chartered Engineers, located at independent sites. Consequently, these engineers were considered proficient "knowledge agents" [52] as their experiences influenced their perception of and consequent application of construction and engineering practices, and the ongoing development of engineering techniques appropriate for site-based radioactive storage development, and their subsequent strategies and goals.

The adopted qualitative research technique used a semi-structured interview process conducted with senior managers/ engineers, whom offered a significant experience factor tuned to the research focus and perspective [53] and this was further facilitated by applying a theory-building approach [54]. Given the level of political and engineering sensitivity surrounding the research issue, its very nature and the lack of appropriately publicised research in this area, this methodology is applied to encourage the development of thick contextual data [55]. A pilot test procedure was carried out with three [3] respondents from the defined population (these were not used in main interview/data collection process - following on from [56] that allowed changes to language and questions that would increase meaning and acceptance by the targeted respondents [57]. This resulted in a more informed and productive question procedure resulting in an enhanced interactive communication with respondents [58].

The population [19] for this study, was made up of Chartered Senior Managers/Senior Engineers who had direct on-site experience for managing similar construction programmes and were situate within a specific civil engineering frame [59]. This provided a focused sampling assessment within clear boundaries [60]. Some individuals in the targeted population were not available for interview during the interview stage or were employed in the pilot study, and the resulting sampling frame was eleven [11] – where all respondents in the targeted population were included [61], and none were left out of scope [62]. Using this qualitative approach [63], participants were selected from within the targeted population [64] which embodied the criteria of notional purposefulness [54]. This was justly applicable for this research [65, 63] and empirically suitable [66] but did not escape empirical judgement [67]. Furthermore, using applicable sampling processes]68], a total of eleven (11) Managers/Senior Engineers constituted the sample frame - stimulated by convenience sampling practices [69]. This meets population saturation requirements [65] towards an empirically accepted degree [70].

Each respondent interview was audio-recorded for potential examination [71] after gaining explicit permission [72]. Interviews were conducted in the English language and took around one hour to complete. Each respondent interview was transcribed verbatim using NVivo 11 [73]. Each interview followed a similar process [74, 75], and utilised the same pre-arranged questions with additional modified supplementary questioning [76- 78]. To enhance confidence in the derived data [79], each transcription was sent back to each respondent [80] - thus applying the process of "validated referral" [81]. Whole-process validity was achieved through linking the research question to the zone of "research focus" [82], as the respondents were considered widely knowledgeable of the context of the research focus [83]. Each interview transcription/dialogue was interrogated leading to independent coding that was correlated with the raised themes [84, 85] and extended through thematic analysis [51]. No part of any interview dialogue was left uncoded and the result unified through a progressive coding-categorisation [86]. Using different data interrogation techniques increased the validity of approaches to analysing key-themes and sub-themes through triangulation [87] and further, content analysis techniques were used to investigate relationships between these [88] and across transcripts [89, 90].

The literature engaged research question was used as a director to examine the research outcome [91, 92]. The developed narrative was created through a mixed methodological approach [58] attempting to establish construct validation [93] underpinned by the notion of observer concurrence in place of strujctural reliability [94] leading to contextual understanding [95].

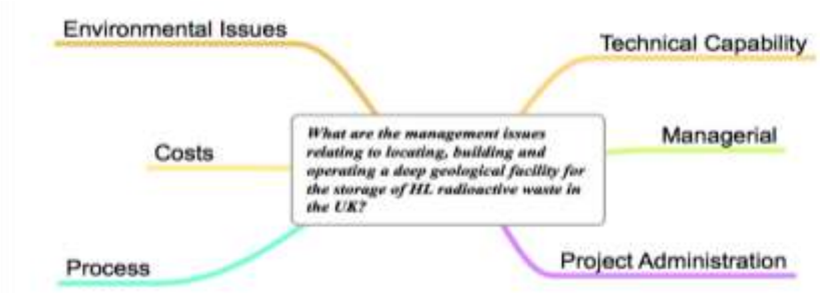

Fig-1: Research Outcomes

Illustration of Research Outcomes

The research outcomes for this research study is shown in Figure 1 above. This structure is illustrated in Table 1 below, and entails six (6) main themes - Technical Capability, Managerial, Project Administration, Environmental Issues, Costs, Process, and subsequent twenty (20) sub-themes. The research interpretations focus on the sub-theme elements within each defined key theme. In line with the research methodological orientation, the reporting format used in this paper reflects a specifically adopted style appropriate to this research scheme [96, 97] utilising appropriate and detailed extractions.

Table 1: Research question, themes and references

Research Question			
What are the management issues relating to locating, building and operating a deep geological facility for the storage of HL radioactive waste in the UK?			
	Main Themes	Sub-Themes	No. Refs
	Managerial	Managerial Intent Ownership Strategy Regulator Security	16 12 11 15 21
	Technical Capability	Design Issues Transport Issues Construction Issues	17 22 14
	Process	Politics Legislation Terminology	27 16 10
	Costs	Design Research Operations	19 12 14
	Project Administration	Project Management Design Capability Project Plans	19 16 13
	Environmental Issues	Failure Issues Leakage Rehabilitation	24 22 14

Table 2: Major themes and respondents

Major Themes	Cited Respondent Number
Managerial	2, 3, 4, 5, 6, 7, 8, 9, 10, 11
Technical Capability	1, 3, 4, 6, 7, 8, 9, 11
Process	1, 3, 5, 6, 7, 10, 11
Costs	4, 8, 9, 10
Project Administration	2, 4, 6, 7, 9, 10
Environmental Issues	1, 5, 3, 8, 9, 11

RESULTS

The outcomes are presented here as six (6) main themes, with twenty (20) sub-themes as indicated in Table 1 and 2 above, and in the discussion each group of sub-themes is placed with each corresponding main theme.

Main Theme – Managerial

Management of the intended DGF project appears to suggest an overwhelming perception of misunderstanding and a lack of insight, leading to a lack of appropriate engagement with the major stakeholders. However, in order to determine a view of the managerial issues surrounding the DGF in relation to this theme:

In terms of Managerial Intent, this is characterized by one respondent (3) who suggested that, *...The intent is described by bureaucrats and not experienced engineers. It is going to result in a huge problem. A huge problem. It doesn't even bear thinking about what they are doing about it…* Another respondent (9) denoted that, *…If the right people are not involved from the beginning, then it will end up a failure, just like the above ground storage facilities at Sellafield at present. Surely the government can see that…*

In terms of Ownership, this is typified by one respondent (7) who advocated that, *…It is clear from discussions with the NDA that they have got it wrong. They are not engineers, they are government scientists and politicians. It is no wonder that the public doesn't trust them with this grave issue…* Another respondent (2) indicated that, *…I am appalled by the naive approach of the government who continues to insist that bureaucrats should run the project rather than engineers…* Another respondent (11) denoted that, *…The running of the project should include local engineers and should be allowed to be run by mining engineers. It's that simple…*

In terms of Strategy, this is represented by one respondent (6) who suggested that, *…It is difficult to know what the government's strategy is now that Cumbria said no, except that I am sure they will impose it on a community, somewhere because of their white paper in 2014. I say put it in London, then we'll be sure it is safe…* Another respondent (4) indicated that, *…One thing is sure, they don't have one.*

In terms of Regulator, this is exemplified by one respondent (10) who advised that, *…Again we have a regulator, the ONR, who doesn't know what to do and hides behind its supposed impartiality as a regulator. It has never regulated anything like this. So how can we trust them? They are just making it up as they go along. Not acceptable in today's climate…* Another respondent (5) suggested that, *…It's the usual clandestine approach. They regulate without telling anyone anything. I am sure that they will also not allow anyone to know where and what is being stored underground…* Another respondent (8) denoted that, *…Just because it's radioactive material doesn't give them the right to do to just what they please. The regulator must have our safety in mind at all times. And to show this clearly and openly. So where is their experience of DGF's?…*

In terms of Security, this is illustrated by one respondent (6) who submitted that, *…It is difficult for some people to accept so much security surrounding the construction and the facilities operation so close to where they live…* Another respondent (2) denoted that, *…Security and secrecy goes together. I am sure that we will not be told exactly what is being stored there and where it is being stored. So it will become a secretive hole in the ground…* Another respondent (11) expressed that, *…Of course the government wants security to be tight on this project, but the regulator needs to be independent and protect us from any issue that is related to the waste. Their job is clearly to make sure we are safe. But I am not sure that will happen because they will compromise our safety…* Another respondent (5) denoted that, *…I am sure that it will be like the Miner's strike with police everywhere. It sure won't be normal for the local people if a DGF was placed near them…*

Main Theme – Technical Capability

At present, the data suggests that there does not seem to be any determination of how the storage facility would be developed underground, or how this material would be stored or the methods adopted to store it safely. There is also the issue of what to do in an emergency, such as digging out a section of the facility in the event of a fire during its operational lifetime. In order to determine a view of the managerial issues surrounding the DGF in relation to this theme:

In terms of Design Issues, this is typified by one respondent (8) who suggested that, …*At present, there are no specific design concepts - they say* [RWM] *this cannot be done because of geological issues, so it won't be available until after the location is chosen*… Another respondent (11) indicated that, …*Conceptually, they must have some idea. Otherwise, it is a knee-jerk reaction*… …*Obviously something could come from other deep storage applications in other countries*… Another respondent (7) expressed that, …*We have no idea what systems will be in place, no management structure, nor do we know who in the local community will be employed and in what position, or the numbers. It's really pathetic*…

In terms of Transport Issues, this is characterized by one respondent (9) who denoted that, …*The location would also have an effect on other factors such as transport arrangements. This is a very big issue, because it will have an effect on other regions. No one wants to have such nuclear waste traipsing through their back-garden...* Another respondent (1) suggested that, …*What about the problem of an accident? Surely, if the facility is operational for 100 years, that something would affect its operations?...* Another respondent (4) designated that, …*If the government wants to push for this, then how about the radioactive waste being stored in London? It is very convenient to say that the geology is not there*…

In terms of Construction Issues, this is exemplified by one respondent (3) who suggested that, …*I'm sorry to say, but there is no construction plans, no methodologies, no protection system, no understanding of testing processes, no... shall I go on*… Another respondent (9) indicated that, …*They are supposed to be delivering a world-class construction project. I see no evidence of this as yet*… Another respondent (6) signified that, …*The site is not managed by a mining engineer, nor a civil engineer or a nuclear engineer. This is rather difficult to accept especially as the construction is on-going for many decades*…

Main Theme – Process

The adopted process appears to be one of hope, rather than a streamlined management process. The initiator of the whole process is signalled by the owner of the project as starting when they have a location. However, good engineering practices indicate that derived management processes can be built. For example, methods of work can be developed and how this fits into the project can be worked on today. In order to determine a view of the managerial issues surrounding the DGF in relation to this theme:

In terms of Politics, this is typified by one respondent (7) who advised that, …*It would be difficult to speculate on when the facility would be built and therefore what geological issues are present until a site is chosen. And that will be further difficult because of localized politics*… Another respondent (10) denoted that, *...It is also a political issue for the region, as it becomes focused on anti-nuclear material, as it has become a problem since the early 80s*… Another respondent (3) expressed that, …*If people knew exactly what transport arrangements were envisaged then no-one would agree to the project go-ahead. At least voluntarily*…

In terms of Legislation, this is epitomized by one respondent (1) who suggested that, …*It is interesting, that the law on constructing underground tunnels and caverns - storage facilities comes under mining law, but this project appears to be treated by the authorities as independent of that*… Another respondent (5) signified that, …*It must be something with the nuclear industry. Their laws operate independently of anything, maybe this is why they don't have any mining engineers running the show*…

In terms of Terminology, this is epitomized by one respondent (6) who advocated that, …*The government uses the term developer instead of constructor or operator, isn't that part of the politics*?... Another respondent (11) denoted that, …*It's called a deep geological facility, don't they mean a deep nuclear burial site*…

Main Theme – Costs

The derived costs appear to be confused and widely disparate - depending on who is asked. Given that the British people were politically lied to by Thatcher in the 80s, then believing the official figures may seem a difficult issue to deal with independently in the attempt to try and understand what is involved in determining a more appropriate and effective cost for the project. In order to determine a view of the managerial issues surrounding the DGF in relation to this theme:

In terms of Design and Construction Costs, this is typified by one respondent (10) who proposed that, …*The costs are phenomenal now, and the government won't release the "actual transfer price" until 30 years after the start of depositing the waste*… Another respondent (9) signified that, …*My understanding is that there is no determination of the* *design, because it is related to the amount of waste for specific types. But surely, they have that, shouldn't they?...*

In terms of Operational Costs, this is typified by one respondent (8) who advised that, …*They haven't released any designs for the storage facility because they don't want to show how costly it will be during the operation of the facility*… Another respondent (4) denoted that, …*There is no schedule of how much waste will be stored and when, even though they know how much is stored at Sellafield at the moment. So it should be easy to determine the underground coverage*…

Main Theme – Project Administration

Since the project relies on a location to store the HLW, the literature appears to accept that nothing can be done operationally until this issue has been decided. However, good engineering suggests that waiting for the contract award before planning the whole project life-cycle is something that is inconceivable today - see for example, any bid process for complex civil engineering projects. So, in this multi-billion pound project it could be envisaged by most stakeholders that cohesive planning and the sharing of that plan is the best way forward. In order to determine a view of the managerial issues surrounding the DGF in relation to this theme:

In terms of Project Management, this is illustrated by one respondent (2) who advocated that, …*It's a pity, but it seems that the managers are not the best. They haven't headed any big projects here or overseas. It's just jobs for the boys*… Another respondent (9) denoted that, …*There doesn't seem to be any professionalism with this group. No one has a relevant mining engineering degree of any kind. It just suggests that no one is really interested in professional management for a project that requires such professionalism*…

In terms of Design Capability, this is exemplified by one respondent (10) who suggested that, …*I can see no justification for many members of this NDA group. They don't even have any designs of any kind at the moment, after 3 years. What have they been doing?...* Another respondent (4) indicated that, …*All projects that I know of have an independent overseeing design component. There doesn't seem to be one here. That's not only bad, but it is probably illegal because its public money being used here*…

In terms of Project Plans, this is typified by one respondent (7) who intimated that, …*I cannot see any plans being devised. Or at least they don't share them. It's a mystery to me*… Another respondent (6) signified that, …*If I run a project without mutual planning, someone would seriously be considering taking action to have me removed. So far, there is only silence. So much for the sharing with the community*…

Main Theme – Environmental

Most stakeholders would expect a full assessment of the environmental impacts, not only because it is a nuclear facility - and will be treated as such - but also to assess the impact across many boundaries associated with possible locations. Further, the present statements of the environmental management are specifically addressed as being solely down to location. This arrogance of stakeholder management may need to be reviewed. In order to determine a view of the managerial issues surrounding the DGF in relation to this theme:

In terms of Failure Issues, this is characterized by one respondent (1) who advocated that, …*Because there aren't any designs yet, it is difficult to evaluate the environmental footprint. But we could speculate more effectively, if we understood why only geologists are involved in the location setting*… Another respondent (5) denoted that, …*No one has tested out the "packages" as yet, in an insitu situation - a deep mine - even without any waste. So, we don't know how they will react, or how they will leak*… Another respondent (9) indicated that, …*We aren't that sure about the robustness of the facilities that are planned. Deep doesn't mean that there won't be any environmental problems because they don't know*…

In terms of Leakage, this is personified by one respondent (3) who submitted that, …*There have been mines where water has leaked out. So what do geologists know that mining engineers don't?...* Another respondent (11) denoted that, …*It is very different having a waste site like this near a community. There are so many environmental problems and leaks caused by such radioactive waste. I am not sure that our systems or their management are that capable*…

In terms of Rehabilitation, this is typified by one respondent (8) who advised that, …*What happens when we find that it is leaking? They have stated that they expect it to leak at some stage. What is the process for rehabilitation? No one wants to talk about this, because they haven't figured it out*… Another respondent (1) conveyed that, …*It seems sensible to plan for possible issues. However, they don't want to talk about this or make it known what could be done. Perhaps they don't know themselves. Obviously, they need to legislate for such things or are we just abandoning this material?*…

DISCUSSION

In order to take this inquiry forward, the discussion concentrates on the raised question to help address any consequent management outcomes. The outcome illustrates the structures informing management practices and to focus on how these influence project outcomes. Consequently, the main focus for this discussion are the characteristics revolving around the main themes - Managerial, Technical Capability, Process, Costs, Project Administration, Environmental Issues, as:

Managerial

From the data, it would appear that no individual in the UK has any experience of DGF construction or consequent operations management. Questions remains as to why the present stated managers, engineers and/or administrators (NDA; ONR; or CoRWM) are best placed to oversee the early stages of this project. However, the NDA does show a named post-closure safety specialist on their website – which isn't likely for another 140 years. It would appear that the present organizational structure is predisposed to bureaucrat administrative engagement, rather than managing technical capability.

There would not appear to be a cohesive strategy related to the DGF location or its build design, where the NDA proposes "waiting" as a strategy before they can design and build the DGF facility. The NDA does not appear to have conducted any overseas discussions with perhaps the Swedish or Finland authorities regarding their disposal issues and design strategies.

Technical Capability

A central theme of this research is the application of the technical need to design and build an appropriate deep-seated facility. The evidence suggests that this is a major issue for the NDA and ONR and that neither have a developed and informed sense of how to physically approach the DGF design and build. For example, when raising the question of *Why 250m – 1000m for a deep geological facility*? This depth seems to reflect an industry-wide acceptance for a DGF, and indicates blind acceptance without any other determining factors. Additionally, if the major principle of Geological Disposal [98] is to develop and use natural barriers (NBS) in tandem with an Engineered Barrier System (EBS), to prevent leakage into the human habitat system at some future point, then surely going deeper is better. If this is the case, then mining engineers are required from day one of the research and not as an additional managerial appendage much later in the DGF programme. Further, this also raises another issue – that of the *Lack of practical testing associated with a DGF facility* as opposed to office-based modelling – not just in relation to the direct protection packages, but also the geological system (NBS) and mining construction approach and methodology (EBS). This has implications for the long-term safety of the DGF, and reflects the difficulty with which the engineering barrier system (EBS) is being ignored with a strenuous focus on the geological issues, rather than the engineering requirements. Using the natural environment as a barrier makes good sense, but to make sure of the immediate protection of the nuclear waste deposit, engineering barriers need to be developed, constructed, tested and approved for the purpose. Consequently, the construction of mined tunnels (part of the EBS) surrounded by natural barriers (NBS) has not been fully/partially tested or modelled [99], but has been advised by the NEA [100]. There has been no credible pilot study conducted to offer some insights about methods of construction for engineered barriers, and little hydrological, thermal conductivity, mechanical or chemical studies carried out relative to considered natural barriers. For example, Bentonite is expected to be the medium for isolation of the packaged cavern from the surrounding rock [101], which is not an engineering conclusive – just arbitrary and ambiguous. Other scientific assessment reveals that Bentonite when exposed to HLW heat, the heat destroys "…*backfill sorbtion and creates cracks for water flow and forces land uplift*" [10]. However, the little evidence that is posed so far, does not point to a sustainable and effectively designed DGF for any country positing the notion of burying nuclear waste of any kind – especially in the UK. Another issues raised is the *Lack of understanding of how distributed the underground storage facility would be* - as an example, Finland is building a DGF at a depth of 455m with at present a designed 2 x 5Km tunnels stretching over 42Kms when fully developed [43]. This has significant implications for the UK site, as presently only consideration is targeted to an area directly under an operational facility – such as at Sellafield. No design outcomes have been published as to the design appropriate assumptions regarding tunnel/cavern sizes or the manner for the distribution of waste within such tunnels/caverns. At a minimum, the number of caverns housing a specific amount of HL waste should be able to be calculated, and added to this the amount/year between now and the estimated closure time – 100 years of operating life, and this should give the volume required. Consequently, it should be feasible for engineers to devise an approximate model of the required tunnels and caverns – even at this stage - which is then modified to correspond with the features and characteristics of any planned location.

Process

The process was a necessary part of the initiation of the DGF programme. Unfortunately, the evidence points to continuing technical and social issues leading back nearly two decades. Further, in relation to the programme developments, there are still issues raised with, for example, *Conflicts and differences in the terminology associated with the DGF* - professionally a deep geological facility would appear to mean something different to a deep underground storage facility. Therefore, this differentiation in terminology may need to be moderated into a single understanding. This possibly reflects both the difficulty of the engineering and the political issues raised when contemplating the design and build of a DGF.

However, the more important issue raised was the political problem, which is likely to be a much larger issue than the engineering or management. Underpinning these is the continuing issue of appropriate legislation and further, the associated problem of forcing a community involvement. In order to move this aspect forward, it would appear that the UK government does not take local politics very seriously and within the scope of ensuring a place for such burial of nuclear waste, has already mandated that the process is now a matter of a unilateral decision to impose the GDF on a community - see, for example - UK Parliament, Order [102, 1].

Costs

Given the fact that no suitable location has been found after 8 years of consideration by the BGS (since 2008 - 14), it is difficult to understand how the financial figure of £4Bn was created by the NDA. This is presumably a result of a proposed budget, rather than any specific and targeted figure related to an apparent design and construction related costs. Further, there is also evidence (see Article 87(1) of the EC Treaty) that payment to the local authority that support such an undertaking may be illegal in Europe as it is subsidising an industry and also considered as "bump" payments *(£1Mn/year for 5 years rising to £2.5Mn as the design and planning becomes more coherent*) which is considerably closer to open-bribery rather than just "paid to engage" [1, 103]. If this was the case, then all such payments should be paid to every local authority to ensure their equal consideration. However, Davey (DECC Secretary) points out that the latest white paper on this issue will mean that local politicians will lose the right of veto [1, 104] meaning that the government will impose the DGF on a community, if a community cannot be found who volunteers to accepts its eventual placement. Further, the data suggests that local authorities who are members of the NFLA, will not be told whether their local authority transport system will experience nuclear waste being transported through their area. This is a secret condition that has yet to be resolved openly. Further, the operating costs of £11.5Bn does not hold any water either, as the amounts of radioactive waste has not been substantially planned, nor drawn out clearly. So again, this is a proposed budget that would appear to misinformed - especially when operating costs have not been aligned in any way.

Of further concern for the UK DGF project, is that France has spent £4.25Mn on underground HLW storage research for the last 5 years (£850Mn/year (39). The UK budget is zero - for any level of waste disposal and this concludes the extended focus of importance by the NDA on location only [23]. This therefore reflects the importance given to focusing on siting the DGF [14]. This is especially a viscous problem, because no research has been published regarding the UK DGF research outcomes in relation to testing rock conditions such as the "technologies to contain the waste." [39].

Project Administration

The evidence relating to project administration suggests that if the mismanagement of the present situation is allowed to continue that this may have a negative effect on the overall management of the project - at least through to its construction. From the evidence, part of this issue revolves around a *Lack of standardized management system for long-term management of the DGF*. This mirrors ultimately, the government approach at the moment as being focused on a very specific aspect of the DGF situation - that of getting the location authorised and accepted by some local population through the local political system [17]. Without developing an appropriate management/monitoring system, it is difficult to understand how the authorities will conduct such actions and leaves difficulties in the notion of believing that the government advisers know what they are doing. This is also a negative reflection on the other major stakeholders - ONR and CoRWM, where the committee advises on the level of regulatory research and development, but is powerless to fund it [105].

Environmental Issues

This is one of the major issues raised through the evidence and one of the issues with the least amount of development. For example, there is no managerial policy regarding managing leakage - except the divisive notion that environmental issues beset the GDF location, build, operation and closure. There is the statement from the NDA [16] that indicates clearly that the NSB nor the ESB barriers are designed not to leak, so there won't be an issue with leakage, so it can be ignored. Since there aren't any designs published to date, it is difficult to determine how any prospective design from the NDA manages the leakage test and at what cost. Consequently, the data further indicates that there is a *Lack of planning to access any DGF - in-case of future need or requirement*. This gives the notion of abandonment more credibility, rather than managed storage. Further, the Finish government appears to mandate that the nuclear waste site at Onkalo (44), when closed will be abandoned and where it is not even necessary for surface marking - which is seen as ignoring natural justice relating to environmental issues [106]. Leakage is still a major issue, as the French research indicates clearly that eventually leakage will "diffuse to the surface" [39,30].

The probability of leakage is of concern not only when the DGF is closed, but more importantly when the facility is in operation. For example, a deep geological waste repository - WIPP (US language) caught fire during operations in February and March 2014 [30], which was closed in March 2014 due to the incident, when 22 workers became contaminated from radiation release above ground and barrel leakage within the facility. It would appear that the management of the site did not "adequately address the fire hazards and risks associated with underground operations" [107]. Since this was the world's only underground nuclear waste disposal in operation at this time, it illustrates clearly that lack of planning and experience in underground situations that may compromise even the best safety system management.

CONCLUSIONS

The kinds of focus used by the UK government appears to be towards restrictive funding and open politics, rather than on generating practical and appropriate radioactive waste management options. This may indicate why the RWM management organisation has no real engineers - mining, civil or nuclear. It also indicates that their management style is bureaucratic in nature [108]; showing a culture of risk-aversion [109, 110]; a lack of leadership [111, 112] and cohesion in planning [113, 114]; and deficiencies in the application of a strategic objectives posture [115]. It also derives an orientation that shows lack of proper communication and direct engagement in stakeholders [116] whilst bordering on intransient attitudes to environmental good governance [117]. Therefore, there is still considerable risk associated with the British DGF project management in terms of their non-performance [118] and their inability to recognize inconsistent and ineffective management [119] and their arrogant disposition for dealing with engineered progress of the GDF project. Consideration may need to be brought by changing the responsibilities and personnel, and enhancing the credibility of the project management of those involved in determining where underground storage of nuclear waste. This would mean a move from being driven by geologists to mining engineers and nuclear engineers. Changing the name of the process from Deep geological storage to Underground Mine storage should also ensure that mining engineers are consulted and become responsible for storing nuclear waste. It is obvious from problems at Sellafield and at other mine storage projects (for example, the US experience) that a more cohesive strategy needs to be employed to ensure the safety of the storage project. Just accepting the regulators statement that the overseeing process will ensure safety at the site isn't acceptable, as they don't have the training nor the experience to oversee or manage in this situation [30].

The "engineered barriers" [120] for HLW storage has not been developed in any form and examples have not been tested insitu, and this brings about the notion of how awkwardly amateurish the present engineering management is considered to be.

The credibility case has not been won by the British government, as it is recognised that that there are extreme failings in the search for a DGF encompassing safe and manageable storage of HLW through inadequate management. Further not one country has established an effective underground on-going DGF facility for HLW, nor has any one country or research facility conducted appropriate underground tests proving the package technology, where the specific parcels of waste elements are subjected to ordinary underground pressures. The DGF notion has further been compromised by the lack of appropriate mining methodology improvements that could be developed without the use of such nuclear waste thus proving or disproving the geological concept of storage. It is thus, ever more disturbing that mining developments have not been tested - irrespective of the nuclear package parameters, as these should have been developed in advance.

Because of the geological leadership given to finding a location for HL Waste, it may now be time for Mining and Nuclear engineering to take the reigns, and lead the DGF project to a more successful conclusion.

The government contravenes its own mine-safety legislation when it allows nuclear authorities and undisclosed administrators to plan/conduct and operate mine development in consequent hazardous operations without appropriate mining engineers on-board leading the development [30]. Managing coal-mines or other dangerous deep mine experience in extreme hazardous situations would appear to be a minimum asset requirement - which in itself is also being contravened, as the present personnel arrangements do not include such experienced personnel.

At present, the government has made a change in the law in 2016 so that it can make unilateral decision to force a DGF site location on a community, which means that the final decision for a DGF is especially political, and does not reflect mining or nuclear engineer's inputs.

It would appear that the French (Cigeo) and Finish (Onkalo) HLW facilities management are far more advanced than the UK DGF project as both have built or extended practical test facilities to explore DGF requirements. Thus, the outcome here is a DGF project in the UK that is blind, and planned without actual test outcomes derived scientifically and methodologically, and is therefore considered, immature, inadequate and unproven with a loosely proposed DGF for nuclear HLW looking for a location.

Further, in 1997, Gummer [121] stated clearly that, he was *...concerned about the scientific uncertainties and technical deficiencies in the proposals presented by Nirex* [and] *about the process of site selection and the broader issue of the scope and adequacy of the environmental statement.* This research paper has revealed that little has changed since 1997 and that the management capability necessary for the planning, building and construction of a DGF in the UK are not available at present, nor for the foreseeable future and that the present agenda needs to be changed to be research-driven, rather utilising an abstract short-term politically oriented agenda.

It appears as a summary, that the location of a DGF site in the UK is at present unknown; the underground design is unknown; the actual costs associated with the underground development is unknown; the capability of the underground design – including the design of the waste packaging for underground use – remains unknown; as well as the technical management orientation which remains unfounded; and the whole engineering compendium remains untested. Therefore, the UK government would appear to want to move the DGF project forward based solely on trust rather than on appropriate scientific and engineering principles.

DECLARATION OF CONFLICTING INTERESTS

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FUNDING

The author received no financial support for the research and/or authorship of this article.

REFERENCES

1. DECC. (2014). Implementing Geological Disposal. Department of Energy, & Climate Change, URN 14D/235, UK Government, July.
2. NDA Annual Accounts. (2012). *NDA Annual Report and Accounts* 2011-12, 28. http://www.nda.gov.uk/documents/upload/AnnualReport-and-Accounts-2011-2012.pdf
3. HM-Treasury. (2012,). Infrastructure investment pipeline. Infrastructure investment pipeline Data: 2012, December. https://www.gov.uk/government/statistics/infrastructure-investment-pipeline
4. NEI. (2011, October). Estimating the disposal costs of spent fuel. Nuclear Engineering International, 45-46. http://www.mng.org.uk/gh/private/jackson_nuclear_waste_disposal.pdf
5. Jackson, I. (2008). Nukenomics: The Commercialisation of Britain's Nuclear Industry. Nuclear Engineering International Special Publications, Progressive Media Markets Ltd., April.
6. Sellafield. (2016). Waste Management facts. http://www.sellafieldsites.com/press-office/facts/wedd-facts/
7. UK Radioactive Waste Inventory. (2016). Waste Inventory Data for Sellafield. https://ukinventory.nda.gov.uk/site/sellafield/
8. Macfarlane, A., & Ewing, R. (2006). Uncertainty Underground: Yucca Mountain and the Nation's High-Level Nuclear Waste, Cambridge, MA: MIT Press, US.
9. Deep Geologic Repository Project. (2016, April). Bruce Nuclear Site (Ontario), Canadian Environmental Assessment Agency, Reference number - 17520.
10. Haszeldine, S. (2013, January). Investigations to site a radioactive waste repository in Cumbria: Evidence against proceeding to MRWS Stage 4. http://www.geos.ed.ac.uk/homes/rsh/Investigations_to_site_a_radioactive_waste_repository_in_Cumbria_4pages_Haszeldine_EVIDENCE_10Jan2013.pdf
11. Bickerstaff, K. (2012). Because We've Got History Here: Nuclear Waste, Cooperative Siting, and the Relational Geography of a Complex Issue. *Environment and Planning, 44*(11), 2611-2628.
12. Kim, J., Kwon, S., Sanchez, M., & Cho, G. (2011). Geological Storage of High Level Nuclear Waste. *KSCE Journal of Civil Engineering, 15*(4), 721-737.
13. Csullog, G., Holmes, R., & Benitez, J. (2001). The Net Enabled Waste Management Database in the Context of an Indicator of Sustainable Development for Radioactive Waste Management. Proceedings of the Waste Management 01 Conference, Tucson, Arizona, USA.
14. IAEA. (2009). Classification of Radioactive Waste. IAEA Safety Standards Series, No. GSG-1.
15. NFLA. (2016,). Briefing 64. Radio Active Waste Policy, June.

16. NDA Strategy, 2016,). Strategy. Nuclear decommissioning Authority, SG/2016/53, March.
17. NDA HAW Strategy. (2016, May). NDA Higher Activity Waste Strategy. https://www.gov.uk/government/publications/nda-higher-activity-waste-strategy
18. DGF, UKGov. (2016). Geological Disposal Facility (DGF) for higher-activity radioactive waste. https://www.gov.uk/government/collections/geological-disposal-facility-DGF-for-high-activity-radioactive-waste
19. BBC. (2013). Cumbria nuclear project rejected by councillors. 30th January. http://www.bbc.com/news/uk-england-cumbria-21253673
20. The Guardian. (2013). Cumbria's nuclear dump can't bury the waste problem. 30th January. https://www.theguardian.com/environment/damian-carrington-blog/2013/jan/30/nuclear-waste-cumbria-copeland-allerdale
21. Flowers Report. (1976). Nuclear Power and the Environment. Cmd, 6618, Sixth Report, Royal Commission on Environmental Pollution, HMSO, London, UK.
22. BGS. (2010). Radioactive waste: siting a repository. Science Briefing, BGS, UK. http://www.bgs.ac.uk/downloads.html
23. NDA NGSG. (2016). Implementing Geological Disposal, Providing Information on Geology. National Geological Screening Guidance, Nuclear Decommissioning Authority, Didcot, UK, March.
24. The Mines Regulations. (2014). Health and Safety Executive, HSE Books**,** Crown Copyright, UK.
25. ONR. (2016a). Geological disposal; ONR's role.. http://www.onr.org.uk/geodisposal.htm
26. Alexander, W., & McKinley, L. (2007). Deep Geological Disposal of Radioactive Waste, Elsevier, London, UK.
27. Pearce, F. (2015). Shocking state of world's riskiest nuclear waste site. New Scientist, 24th January.
28. World Nuclear News. (2014). New UK waste facilities completed. 16th May. http://www.world-nuclear-news.org/WR-New-UK-waste-facilities-completed-1605144.html
29. ONR. (2016c). Licence condition handbook, January. http://www.onr.org.uk/documents/licence-condition-handbook.pdf
30. Wise International. (2014). Fire and leaks at the world's only deep geological waste repository. 6th March. https://www.wiseinternational.org/nuclear-monitor/787/fire-and-leaks-worlds-only-deep-geological-waste-repository
31. OECD / NEA. (1984). Paris.
32. NEA. (2016). Nuclear Energy Agency https://www.oecd-nea.org/brief/brief-03.html, and, http://www.oecd-nea.org/rwm/igsc/docs/igsc-safety-case-letter.pdf
33. RWI. (2004). The 2004 UK Radioactive Waste Inventory: Main Report. Department for Environment, Food and Rural Affairs and United Kingdom Nirex Ltd, October 2005. Report DEFRA/RAS/05.002 and Nirex Report N/090.
34. DBEIS. (2014). Geological disposal of radioactive waste: a guide for communities. Department for Business, Energy & Industrial Strategy, 2013, July. https://www.gov.uk/guidance/managing-radioactive-waste-safely-a-guide-for-communities
35. Chan, S., & Harvey, J. (2013). Transporting Radioactive Materials to a Geological Disposal Facility – An Integrated Approach. Proceedings of the 17th International Symposium on the Packaging and Transportation of Radioactive Materials, PATRAM 2013, August 18-23, 2013, San Francisco, CA, USA, 1-7.
36. Delay, J., Lesavre, A., & Wileveau, Y., 2008). The French underground research laboratory in Bure as a precursor for deep geological repositories. *Reviews in Engineering Geology*, *19*, 97-111.
37. World Nuclear News. (2012). Next phase for French geological disposal. 5th January.http://www.world-nuclear-news.org/wr-next_phase_for_french_geological_disposal-0501127.html
38. Andra. (2016). Waste management. 1610. https://www.andra.fr/international/pages/en/menu21/waste-management/waste-classification/high-level-waste-and-long-lived-intermediate-level-1610.html
39. BureLab. (2010). France digs deep for nuclear waste. *Nature*, *466*, 804-805.
40. NEI. (2014). Building Dounreay's LLW vaults. 13th November. http://www.neimagazine.com/features/featurebuilding-dounreays-llw-vaults-4435386/
41. SCX. (2016). SCX "Special Projects Wins Dounreay Contract. January. http://www.scxspecialprojects.co.uk/News/SCX-Special-Projects-Wins-Dounreay-Contract/
42. The Netherlands. (2009). Peer Review of the Radioactive Waste Management Activities of Covra, Netherlands. IAEA, Nov-Dec.
43. Onkalo. (2016). Final disposal. Onkalo, Posiva. http://www.posiva.fi/en/final_disposal/onkalo#.V7wv4LVWnUI
44. ABC.Net. (2016). Finland to bury nuclear waste for 100,000 years in world's costliest tomb. 8th June. http://www.abc.net.au/news/2016-06-08/finns-to-bury-nuclear-waste-in-world's-costliest-tomb/7488588
45. IAEA.org. (2016a). Storage and Disposal of Spent Fuel and High Level Radioactive Waste. 4-5.

https://www.iaea.org/About/Policy/GC/GC50/GC50InfDocuments/English/gc50inf-3-att5_en.pdf
46. IAEA.org. (2016b). Standards. http://www-ns.iaea.org/standards/documents
47. ONR. (2016b). A guide to Nuclear Regulation in the UK. Office of Nuclear Regulation, 2016 update. http://www.onr.org.uk/documents/a-guide-to-nuclear-regulation-in-the-uk.pdf
48. Arksey, H., & O'Malley, L. (2005). Scoping studies: towards a methodological framework. *International Journal Social Research Methodology, 8*(1), 19-32.
49. Househ, M. (2011). Sharing sensitive personal health information through Facebook: the unintended consequences. *Studies in Health Technology Informatics, 169*, 616-620.
50. Hill, C. E., Thompson, B. J., & Williams, E. N. (1997). A guide to conducting consensual qualitative research. *The Counseling Psychologist, 2*5(4), 517-572.
51. Walsh, S. P., White, K. M., & Young, R. M. (2008). Over-Connected? A Qualitative Exploration of the Relationship between Australian Youth and Their Mobile Phones. *Journal of Adolescence, 31*(1), 77-92.
52. Benn, N., Buckingham, S., Domingue, J., & Mancini, C. (2008). Ontological Foundations for Scholarly Debate Mapping Technology. *In: 2nd International Conference on Computational Models of Argument (COMMA '08), Toulouse, France.*
53. Cassell, C., & Symon, G. (2004). Essential Guide to Qualitative Methods in Organizational Research, Sage Publications, London, UK.
54. Glaser, B.G., & Strauss, A.L. (1967). The Discovery of Grounded Theory: Strategies for Qualitative Research, Aldine, Chicago, US.
55. Cayla, J., & Eckhardt, G.M. (2007). Asian Brands without Borders: Regional Opportunities and Challenges. *International Marketing Review, 24*(4), 444-456.
56. Maxwell, J. (2013). Qualitative Research Design: An Interactive Approach: An Interactive Approach, Sage Publications, London, UK.
57. Kim, Y. (2011). The Pilot Study in Qualitative Inquiry: Identifying Issues and Learning Lessons for Culturally Competent Research, Qualitative Social Work, 10(2), 190-206.
58. James, P., & James, T., 2011, Qualitative Research Methods for Health Services, Magellan UK Press, London, UK.
59. Ritchie, J., & Lewis, J. (2003). Qualitative Research Practice: A Guide for Social Science Students and Researchers, Sage Publications, London, UK.
60. Coyne, I.T. (1997). Sampling in qualitative research: purposeful and theoretical sampling; merging or clear boundaries? *Journal of Advanced Nursing, 26*(3), 623-630.
61. Fink, A.S. (2000). The Role of the Researcher in the Qualitative Research Process. A Potential Barrier to Archiving Qualitative Data. Forum: *Qualitative Social Research, 1*(3), article 4.
62. Koerber, A., & McMichael, L. (2008). Qualitative Sampling Methods: A Primer for Technical Communicators. *Journal of Business and Technical Communication, 22*(4), October, 454-473.
63. Bryman, A. (2012). Social Research Methods, Oxford University Press, Oxford, UK.
64. Carman, J.M. (1990). Consumer Perceptions of Service Quality: An Assessment of the SERVQUAL Dimensions. *Journal of Retailing, 66*(1), 33-55.
65. Guest, G., Bunce, A., & Johnson, L. (2006). How Many Interviews Are Enough? An Experiment with Data Saturation and Variability. *Field Methods, 18*(1), 59-82.
66. Spanos, A. (1990). Towards a Unifying Methodological Framework. In: Modelling Economic Series: Readings in Econometric Methodology, In: William, C. & Granger, J. Readings in Econometric Methodology, Clarendon Press, Oxford, UK.
67. Crouch, M., & McKenzie, H. (2006). The logic of small samples in interview-based qualitative research. *Social Science Information, 45*(4), 483-499.
68. Glaser, B.G. (2004). Remodeling Grounded Theory, The Grounded Theory Review: *An international Journal, 4*(1), 1-24.
69. Harrel, G.D., & Fors, M.F. (1995). Marketing services to satisfy internal customers, *Logistics Information Management. 8*(4), 22-27.
70. Miles, M., & Huberman, M. (1994). Qualitative data analysis: An expanded sourcebook, Sage Publications, Thousand Oaks, CA, US.
71. Gill, P., Stewart, K., Treasure, E., & Chadwick, B. (2008). Methods of data collection in qualitative research: interviews and focus groups. *British Dental Journal, 204*, 291-295.
72. Duranti, A. (2007). Transcripts, like Shadows on a Wall. *Mind, Culture, and Activity, 13*(4), 301-310.
73. Bailey, K.D. (2008). Methods of Social Research. The Free Press, NY, US.
74. Gray, J., & Wilcox, B. (1995). Good Schools, Bad Schools, Open University Press, UK.
75. [James, P. (2014). Managerial Challenges Impacting on Contractor Led Tunnel TBM Design: A Kingdom of Saudi Arabia Metro Project., Engineering Management Research, 3(2), November.
76. Balshem, M. (1991). Cancer, Control and Causality: Talking about Cancer in a Working-

Class Community. *American Ethnologist, 18*(1), 152-172.
77. Punch, K. (2014). Introduction to Social Research: Quantitative and Qualitative Approaches, Sage Publications, London, UK.
78. Meurer, W. J. (2007). Qualitative Data Collection and Analysis Methods: The INSTINCT Trial. *Academic Emergency Medicine, 14*, 1064-1071.
79. Curry, L., Nembhard, I., & Bradley, E. (2009). Qualitative and Mixed Methods Provide Unique Contributions to Outcomes Research. *Circulation, 119*, 1442-1452.
80. Harris, L., & Brown, G. (2010). Mixing interview and questionnaire methods: Practical problems in aligning data. *Practical Assessment, Research and Evaluation, 15*(1), 1-19.
81. Reeves, T.K., & Harper, D. (1981). Surveys at Work, McGraw-Hill, London, UK.
82. Stenbacka, C. (2001). Qualitative research requires quality concepts of its own. Management Decision, 39(7), 551-556.
83. Tull, D.S., & Hawkins, D.I. (1990). Marketing Research: Measurement and Method, Macmillan, London, UK.
84. Glaser, B.G. (1992). Basics of grounded theory analysis: Emergence vs. Forcing, Mill Valley, Sociology Press, CA, US.
85. Strauss, A.L., & Corbin, J. (1990). Basics of Qualitative Research: Grounded Theory, Procedures and Techniques, Sage, Newbury Park, Chicago, US.
86. Buston, K. (1999). NUD*IST in action: its use and its usefulness in a study of chronic illness in young people, In: Bryman A., & Burgess R.G., (Eds.) Analysis and Interpretation of Qualitative Data, Sage Publications, London, UK.
87. Onwuegbuzie, A. J., & Leech, N. L. (2007). Sampling Designs in Qualitative Research: Making the Sampling Process More Public. *The Qualitative Report, 12*(2), 238-254.
88. Harwood, T.G., & Garry, T. (2003). An Overview of Content Analysis. *The Marketing Review, 3*(4), 479-498.
89. Reisman, C.K. (1993). Narrative Analysis, Sage, London, UK.
90. Ryan, G.W., & Bernard, H.R. (2003). Techniques to Identify Themes. *Field Methods, 15*(1), 85-109.
91. Yin, R.K. (1994). Case study research: Design and methods, Sage Publications, Newbury Park, CA, US.
92. Hammersley, M., & Atkinson, P. (1995). Ethnography: principles in practice, Routledge, London, UK.
93. Healy, M., & Perry, C. (2000). Comprehensive criteria to judge validity and reliability of qualitative research within the realism paradigm. Qualitative Market Research: *An International Journal, 3*(3), 118-126.
94. Golafshani, N. (2003). Understanding Reliability and Validity in Qualitative Research. The Qualitative Report, 8(4), 597-606.
95. Lincoln, Y.S., and Guba, E.G. (1985). Naturalistic Inquiry, Sage Publications, Beverly Hills, US.
96. Gonzalez, C. (2008). Conceptions of, and approaches to, teaching online: a study of lecturers teaching postgraduate distance courses. *Higher Education, 57*(3), 299-314.
97. Daniels, J.A., et al. (2007). The Successful Resolution of Armed Hostage/Barricade Events in Schools: A Qualitative Analysis. *Psychology in the Schools, 44*(6), 601-613.
98. DBEIS. (2016). Geological Disposal Facility (DGF) for higher-activity radioactive waste. Department for Business, Energy & Industrial Strategy, 2016, July. www.gov.uk/government/collections/
99. NDA. (2013). Geological Disposal: Framework for Application of Modelling in the Radioactive Waste Management Directorate. NDA Report no. NDA/RWMD/101, September.
100. NEA. (2001). The Role of Underground Laboratories in Nuclear Waste Disposal Programmes. RWM, October. https://www.oecd-nea.org/rwm/reports/2001/nea3142.pdf
101. Sellin, P., & Leupin, O. (2013). The Use of Clay as an Engineered Barrier in Radioactive-Waste Management – A Review. *Clays and Clay Minerals, 61*(6), 477-498.
102. [UK Parliament, order. (2015). Appendix 1: Draft Infrastructure Planning (Radioactive Waste Geological Disposal Facilities) Order 2015. http://www.publications.parliament.uk/pa/ld201415/ldselect/ldsecleg/102/10204.htm
103. BBC. (2014). Local politicians to lose nuclear waste site veto right. 24th July. http://www.bbc.com/news/science-environment-28463042
104. Town and Country Planning. (2014). a geological disposal facility for nuclear waste – if not Sellafield, then where? December. http://www.tcpa.org.uk/data/files/Journal_Blurb__Sample_Articles/December_2014_Sample.pdf
105. NEA RWM. (2010). Regulatory Research for Waste Disposal – Objectives and International Approaches - Draft. Nuclear Energy Agency, Radioactive Waste Management Committee, NEA/RWM/RF(2010)1. https://www.oecd-nea.org/rwm/docs/2010/rwm-rf2010-1.pdf
106. Kyne, D., Bolin, B. (2016). Emerging Environmental Justice Issues in Nuclear Power and Radioactive Contamination. *International Journal of Environmental Research and Public Health, 13*(7), 700.

107. DNFSB. (2011). Fire protection programme, Waste Isolation Pilot Plant. 24th June. http://www.dnfsb.gov/board-activities/reports/staff-issue-reports/fire-protection-program-waste-isolation-pilot-plant
108. Ivancevich, J., Konopaske, R., & Matteson, M. (2007). Organization Behaviour and Management, McGraw-Hill Irwin, New York, US.
109. Bozeman, B., & Kingsley, G. (1998). Risk Culture in Public and private Organisations. *Public Administration review*, *58*(2), 109-118, March/April.
110. Schein, E. (1985). Organisational Culture and Leadership, Jossey-Bass, SF, US.
111. Avolio, B.J., Walumbwa, F.O., & Weber, T.J. (2009). Leadership: Current Theories, Research, and Future Directions. *Annual Review of Psychology 60*, 421-449.
112. Yukl, G. (2013). Leadership in Organisations, Pearson, NY, US.
113. Berry, F. (1994). Innovation in public management: the adoption of strategic planning. *Public Administration Review*, *54*(4), 322-330.
114. Hough, M., & Spillan, J. (2005). Crisis Planning: Increasing Effectiveness, Decreasing Discomfort. *Journal of Business & Economics Research*, *3*(4), 19-24.
115. Drucker, P. (2014). The Practice of Management, Harper-Business, NY, US.
116. Olander, S. (2007). Stakeholder impact analysis in construction project management. *Construction Management and Economics*, *25*(3), 277-287.
117. Glasbergen, P., Biermann, F., & Mol, A. (2007). Partnerships, Governance and Sustainable Development, Elgar, Cheltenham, UK.
118. Bernold, S., & AbouRizk, S. (2010). Managing Performance in Construction, John Wiley & Sons, NJ, US.
119. Serpella, A., Ferrado, X., Howard, R., & Rubio, L. (2014). Risk Management in Construction Projects: A Knowledge-based Approach. *Procedia - Social and Behavioral Sciences, 119*, 653-662.
120. BGS. (2016). Radiation and Radioactivity. http://www.bgs.ac.uk/research/minerals/radiationAndRadioactivity.html
121. Gummer, J. (1997). Rejection of Nirex Planning application. s4.2, 17th March. http://www.publications.parliament.uk/pa/cm200910/cmselect/cmenergy/memo/nps/uc5302.htm