LUT University

School of Energy Systems

Energy technology

Master's thesis

Identifying gaps and possible improvements in Loviisa Nuclear Power Plant's performance

Loviisan ydinvoimalaitoksen suorituskyvyn kehityskohteiden ja parannusmahdollisuuksien tunnistaminen

Examiners: Professor Juhani Hyvärinen

M.Sc. (Tech) Jukka Päivärinta

Instructors: Professor Juhani Hyvärinen

M.Sc. (Tech) Jukka Päivärinta

Loviisa 3.4.2020

Aleksi Hassinen

ABSTRACT

Aleksi Hassinen
School of Energy Systems
Energy technology

Identifying gaps and possible improvements in Loviisa Nuclear Power Plant's performance

Master's thesis 2020
Examiners: Professor Juhani Hyvärinen & M.Sc. (Tech) Jukka Päivärinta
84 pages, 19 figures and 5 tables
Keywords: Nuclear Power Plant, High Reliability Organisation, Performance Improvement

This thesis was made to discover improvement areas in Loviisa Nuclear Power Plant's performance by comparison to High Reliability Organisation characteristics. Thesis included literature sources of organisation structures, High Reliability Organisation model and evaluation reports made for Loviisa Nuclear Power Plant.

The results were concluded with comparison between High Reliability Organisation characteristic and Loviisa Nuclear Power Plant's current performance stated by evaluation reports. Several gaps and strengths were found in Loviisa Nuclear Power Plant's performance comparing it to High Reliability Organisation characteristics.

In conclusion, Loviisa Nuclear Power Plant's performance is at a good level, although some improvement possibilities were also identified. It was also observed that Loviisa Nuclear Power Plant has a healthy organisational culture and good possibility to close the gaps to meet the High Reliability Organisation standards.

TIIVISTELMÄ

LUT University
School of Energy Systems
Energiatekniikan koulutusohjelma

Aleksi Hassinen

Loviisan ydinvoimalaitoksen suorituskyvyn kehityskohteiden ja parannusmahdollisuuksien tunnistaminen

Diplomityö 2020
84 sivua, 19 kuvaa ja 5 taulukkoa
Tarkastajat: Professori Juhani Hyvärinen ja DI Jukka Päivärinta
Hakusanat: Ydinvoimalaitos, korkean luotettavuuden organisaatio, suorituskyvyn kehittäminen

Tämän diplomityön tarkoitus oli löytää Loviisan ydinvoimalaitoksen kehityskohteita verrattuna korkean luotettavuuden organisaatiomalliin. Diplomityössä käytettiin kirjallisuuslähteitä organisaatiorakenteista ja korkean luotettavuuden organisaatiomallista. Lisäksi työssä käytettiin Loviisan ydinvoimalaitokseen kohdistuneita arviointiraportteja.

Työn tuloksissa verrattiin korkean luotettavuuden organisaatiomallin ja Loviisan ydinvoimalaitoksen suorituskyvyn eroja. Loviisan ydinvoimalaitoksen suorituskyvyn arviointi perustui arviointiraporttien havaintoihin.

Johtopäätöksenä Loviisan ydinvoimalaitoksen suorituskyky on hyvällä tasolla, vaikka kehittämiskohteita on tunnistettavissa. Työssä tunnistettiin myös, että Loviisan ydinvoimalaitoksessa on terve organisaatiokulttuuri ja sillä on hyvät mahdollisuudet päästä kaikilla osa-alueilla korkean luotettavuuden organisaation tasolle.

TABLE OF CONTENTS

ABBREVATIONS

CAP	Corrective Action Program
CEO	Chief Executive Officer
CMS	Combustible Material Storage
HR	Human Resources
HRO	High reliability organisation
IAEA	International Atomic Energy Association
LTO	Long Term Operation
MW	Megawatt
NPP	Nuclear Power Plant
OSART	Operational Safety Review Team
PWR	Pressurized water reactor
SIPOC	Suppliers, Inputs, Process, Outputs and Customers
SAT	Systematic Approach to Training
WANO	World Association of Nuclear Operators

1 INTRODUCTION

This thesis is done for Loviisa Nuclear Power Plant (henceforth Loviisa NPP) and under employment of the Fortum Power and Heat Oy in Loviisa NPP. Loviisa NPP is owned by Fortum Power and Heat Oy which is, in turn, fully owned by Fortum Oyj. The objective of the thesis is to identify performance improvement areas for Loviisa NPP with the support of literature sources and evaluation reports made to Loviisa NPP.

1.1 Background

Organisations are defined as a "social entities that are goal-directed, are designed as deliberately structured and coordinated activity systems, and are linked to the external environment" (Daft, Murphy & Willmott, 2010). More specifically, organisation structure is a tool for achieving organisation's goals. It determines how different components and dimensions are organised in the organisation (Huczynski & Buchanan, 2001). If the goals are well defined, an effective organisation structure can directly impact on the achievement of these goals. Therefore, organisation structure and its effectiveness are indeed an area of interest. Also, increased competition in cost, quality and technical changes force businesses to rethink the way of doing old tasks and to consider new approaches in organising old or new tasks (Hernaus, 2008).

Range of organisation structures and models are identified and studied but it is also worth to note that organisation structures usually vary from each other and they are not only a single type of organisation (Huczynski & Buchanan, 2001). Hence, it is also worth to explore which aspects of different structures and models work in a particular environment and particular organisation. In this thesis the current organisation structure in Fortum Oyj is formed with divisional structure and a part of that is the case study of Loviisa NPP, which has functional organisation structure.

1.2 Scope and goals

The main research question is:

- What are the gaps and possible improvements of Loviisa Nuclear Power Plant's performance?

Sub research questions are:

- What are the identified strengths in Loviisa NPP?
- What are the identified gaps in Loviisa NPP?
- What improvements could be done in Loviisa NPP?

The goal of this thesis is to identify both gaps and possible improvements of Loviisa Nuclear Power Plant's performance. This is also the main research question in which the thesis focuses on. The sub research questions are created to specify the main research question. The first sub research question's goal is to identify the strengths of Loviisa NPP. The second sub research question is created to identify the gaps in Loviisa NPP. The goal of the third sub research question is to identify possible improvements that could be done in Loviisa Nuclear Power Plant.

The scope of this thesis includes introduction to Loviisa NPP, literature review, processing of evaluations done for Loviisa NPP, results and conclusions. Chapter 2 describes the basic structure of Loviisa NPP and the organisation structure of Loviisa NPP and the Fortum Oyj. As Loviisa NPP is performing well based on safety and availability, this thesis specifies more into the organisational point of view of Loviisa NPP.

Chapter 3 focuses on studying different organisation structures and models as well as finding new aspects and practices that would support the case subject Loviisa NPP. More particularly, five different organisational structures and models are studied with theoretical literature sources and thus the support of empirical studies regarding other organisations which operate in safety critical environments. In particular, this thesis specialises in the High Reliability Organisation theory model in chapter 3.5. All literature research is aimed to support the case subject Loviisa NPP, which can be identified as a large organisation in a safety critical environment.

Chapter 4 includes evaluations conducted for Loviisa NPP in the recent years. The evaluations are gathered from several internal and external sources. Further, the

evaluations include independent external parties from Finland and abroad and also internal parties from Loviisa NPP. The content of the evaluation reports is already reviewed and therefore this thesis does not particularly question the correctness of the evaluations.

Chapter 5 focuses on combining the theoretical and empirical findings from different literature sources and evaluation reports conducted for Loviisa NPP and trying to find gaps in Loviisa NPP's current performance and possible improvement possibilities. Lastly, chapter 6 contains the conclusion of the findings and review of the success in answering the research questions.

2 LOVIISA NUCLEAR POWER PLANT

2.1 Introduction to Loviisa Nuclear Power Plant

Loviisa Nuclear Power Plant (Loviisa NPP) has two VVER pressurized water reactors (PWR) named Loviisa 1 and Loviisa 2. Both units have capacities of 507 MW net. Commission for Loviisa 1 started in 1977 and for Loviisa 2 in 1980. The current operating licence for Loviisa 1 is until year 2027 and for Loviisa 2 licence is valid until 2030. Loviisa NPP has approximately 500 permanent employees and 100 external employees. During annual outage, the number of external employees increases between 700 – 1300. The basic structure of Loviisa Nuclear Power plant is described below in Figure 1 (Fortum Oyj, 2019).

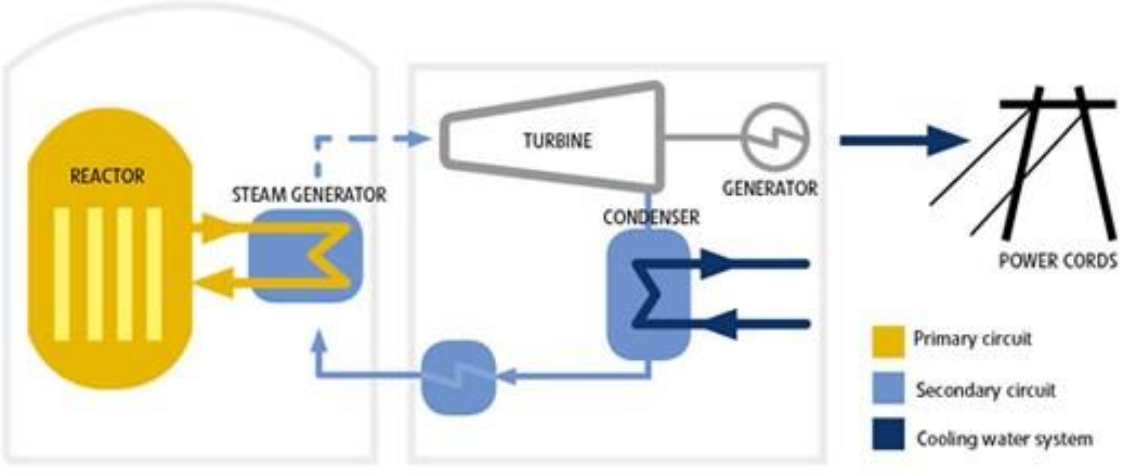

Figure 1. Loviisa NPP basic structure (Fortum Oyj, 2019).

Pressurized water reactors (PWR) have two cooling circuits: primary circuit and secondary circuit. Primary circuit transfers heat from reactor to steam generators through main circulating water pumps. In the steam generator the heat is transferred through heat transfer pipes into the secondary circuit. Because the pressure in the secondary circuit is lower than in the primary circuit, the water boils in the secondary circuit's steam generator. Generated steam is circulated to the turbine where the expanding steam's thermal energy is transferred to kinetic energy and further to electricity through generator which is connected to the turbine. The steam is transferred from the turbine to the

condenser where the steam condenses into water and is then pumped to the feed water tank and from there pumped again to the steam generator. The condenser is cooled with sea water. (Eurasto, Järvinen, Sandberg & Sjöblom, 2004.)

2.2 Current organisation structure

The current organisation structure is described in this section from Loviisa Nuclear Power Plant's point of view. First, the company Fortum Oyj and the governing bodies are introduced. After the company introduction, the generation division and the license holder's organisation are described. In the last section, Loviisa Nuclear Power Plant is introduced more specifically.

2.2.1 Fortum

Fortum Oyj is a large energy company and its core business operates in ten different countries. Employee count was around 8 300 and sales 5 242 million euros in 2018 (Fortum Oyj, 2019). The governing bodies of Fortum are described in Figure 2.

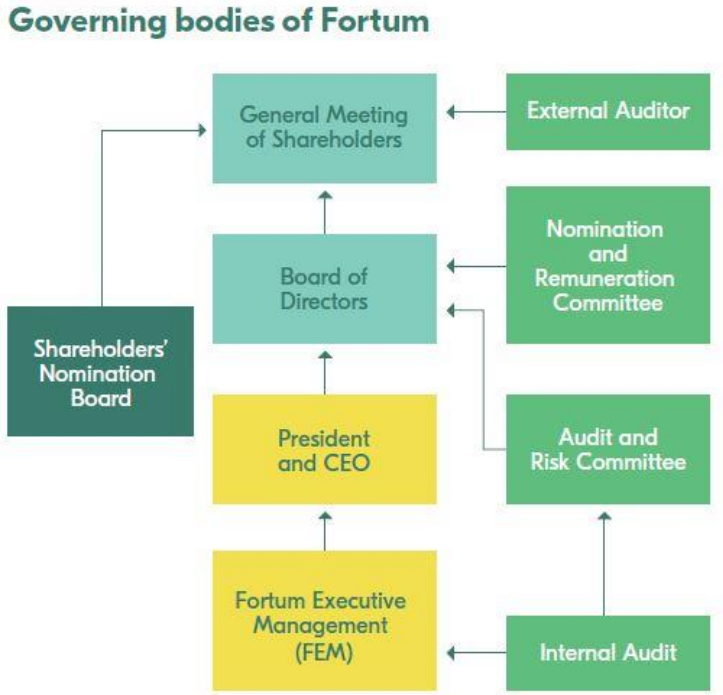

Figure 2. Governing bodies of Fortum (Fortum Oyj, 2019).

The governing bodies of Fortum consist of Shareholders' Nomination Board, which tasks are to propose the structure of Board of Directors to the Annual General Meeting (Fortum Oyj, 2019). The Board of Directors have two committees, namely Audit and Risk Committee and Nomination and Remuneration Committee. Next governing body is President and CEO who are supported by the Fortum Executive Management. (Fortum Oyj, 2019.)

Fortum Oyj's organisation chart is described in the following Figure 3:

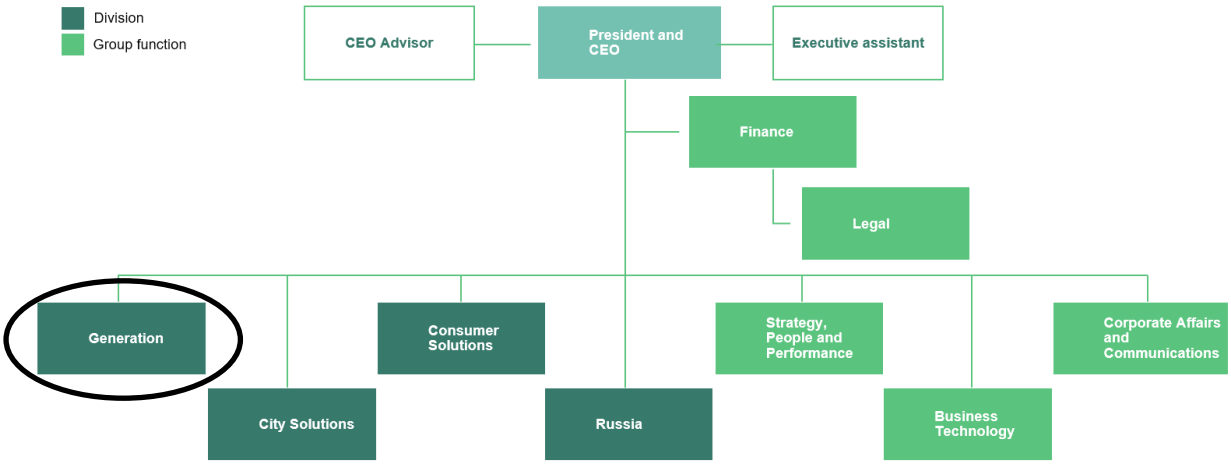

Figure 3. Fortum's organisation (Fortum Oyj, 2019).

First, there is President and CEO with supporting functions, namely CEO advisor and Executive assistant. The business divisions are separated into four divisions: Generation, City Solutions, Consumer Solutions and Russia. In addition, there are five group functions: Finance, Legal, Strategy, People and Performance, Business Technology and Corporate Affairs and Communications (Fortum Oyj, 2019). The Generation division is highlighted in the figure since this thesis will focus on the Loviisa Nuclear Power plant which is under the Generation division.

2.2.2 Generation division

Generation division consists of the Nordic power production. The Nordic power production includes nuclear, hydro and thermal power productions. It also includes portfolio management, trading and industrial intelligence as well as nuclear services on a

global scale. (Fortum, 2019.) Loviisa NPP is highlighted as a point of interest in this thesis.

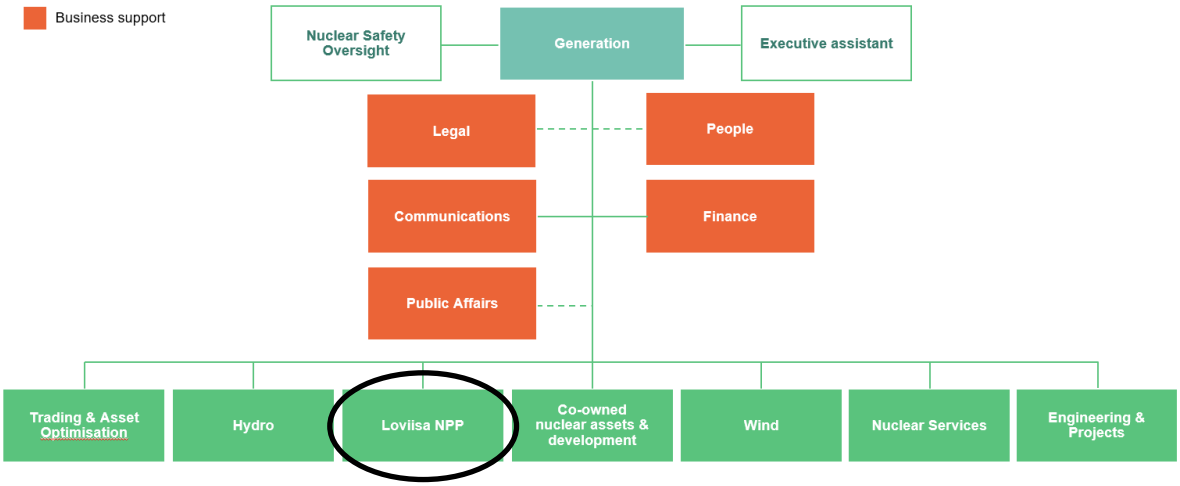

Figure 4. Generation division organisation (Fortum Oyj, 2019).

2.2.3 License holder

Loviisa Nuclear Power Plant is owned by Fortum Power and Heat Oy and it is 100 percent subsidiary company of Fortum Oyj. The subsidiary company Fortum Power and Heat Oy is a juridical license holder of using nuclear energy. Some of the main responsibilities of the license holder are:

- Safe usage of nuclear power, security arrangements and standby arrangements (Nuclear Energy Act, 990/1987).
- Radiation safety of using nuclear power and other radiation related functions (Säteilylaki, 859/2018).
- Managing nuclear waste and its expenses (Nuclear Energy Act, 990/1987).
- Preparations for the nuclear accident (Ydinvastuulaki, 484/1972).
- Be responsible as a company for operating the power plant as regulations and operating conditions state (Mäkinen, 2019).
- Continuous improvement of the management system (STUK, 2019).

The license holder's organisation is described in Figure 5 below.

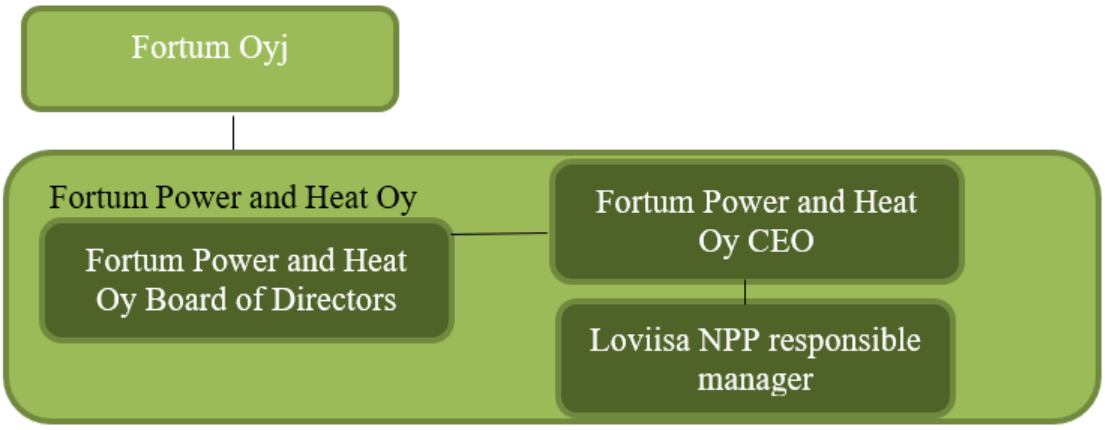

Figure 5. License holder's juridical organisation.

Fortum Power and Heat Oy Board of Directors is responsible of creating environment and qualifications to meet the requirements which are given to the license holder. Board of directors also defines the responsible manager and his/her substitutes for Loviisa NPP. Fortum Power and Heat Oy CEO is responsible for operation in Fortum Corporate's operative organisation according to applicable laws and regulations and by the guidance given by the Fortum Power and Heat Oy Board of Directors. Loviisa Nuclear Power Plant's responsible manager is accountable for making sure that given regulations, orders and license conditions are followed in the operating of nuclear energy, security and emergency preparedness arrangements, nuclear material safeguards and safe radiation usage. (Mäkinen, 2019.)

2.2.4 Loviisa Nuclear Power Plant

The main purpose on Loviisa Nuclear Power Plant's business area is to operate Loviisa NPP safely, reliably and economically. Loviisa Nuclear Power Plant's Responsible Manager is the General Manager. (Mäkinen, 2019.) The organisation structure of Loviisa NPP is described in Figure 6.

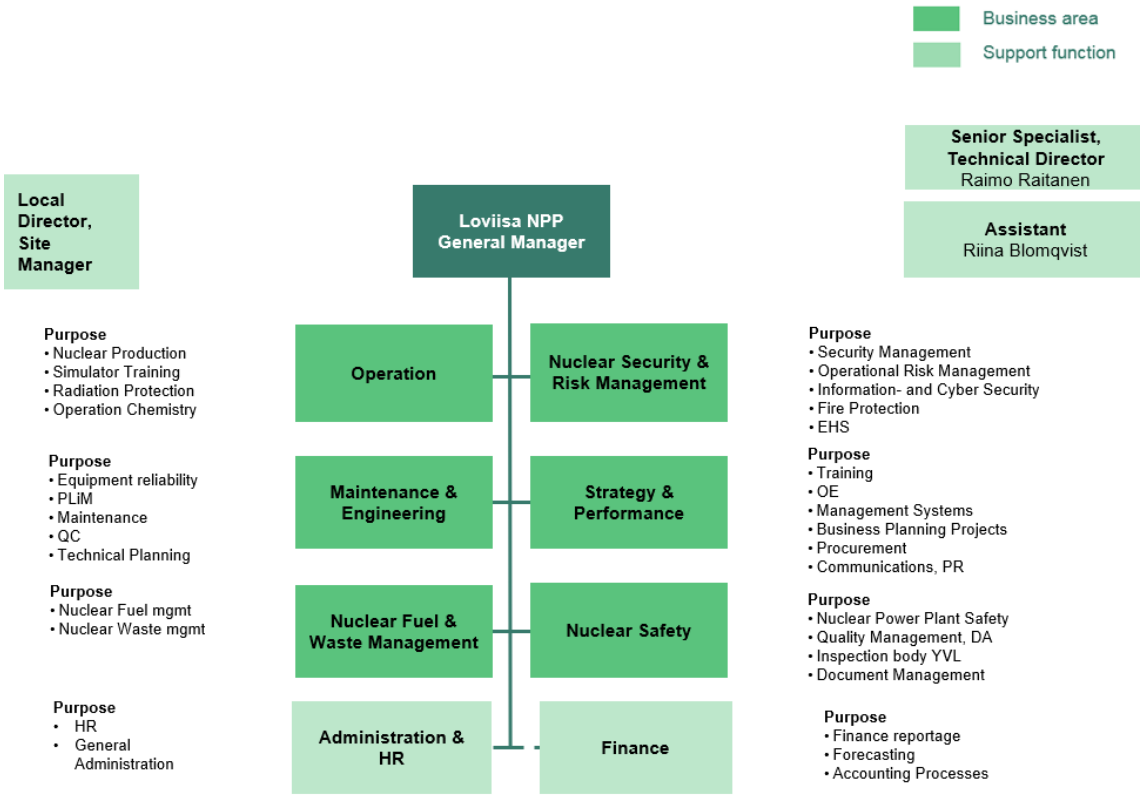

Figure 6. Loviisa NPP's organisation structure.

Loviisa Nuclear Power Plant is divided into eight units. Operation unit is responsible for the Power Plant's electricity production and the use of processes safely and economically. Moreover, Operation unit includes also chemistry management, radiation safety, Foreign Material Exclusion (FME) management, operation development and participating in plant related projects. (Eurasto, 2019.)

Maintenance & Engineering unit is responsible for creating conditions for safe and efficient electricity production (Inkala, 2017). A part of Maintenance & Engineering unit is Planning group which includes processes, machinery, electric, automation and infrastructure related to technical planning. Other notable functions are Operation lifetime management, Reliability management and aging management. (Laakso, 2019.)

Nuclear Fuel & Waste Management unit's responsibilities are to take care of new and used fuel rods and further to take care of radioactive waste. The unit is also responsible for making sure that fuel rods and nuclear waste fulfil their requirements and therefore ensure reliable, safe and economical operating of the power plant. (Tuunanen, 2018.)

Nuclear Security & Risk Management's responsibilities are Fire Protection, Security Management and Operational Risk Management. Responsibilities also include Environment, Health and Safety (EHS) procedures, which laws and standards define. (Vanhanen, 2019.)

Strategy & Performance's responsibility is to deliver support to other units at Loviisa Nuclear Power Plant. Some of the functions are: Training, Operational Experience, Business Planning, Business Analysis, Nuclear communications and Procurement. (Päivärinta, 2019.)

Finally, the whole organisation chart from the top to Automation Maintenance group in Loviisa NPP is presented in Figure 7. In this example Maintenance & Engineering has six other group functions in addition to Automation Maintenance.

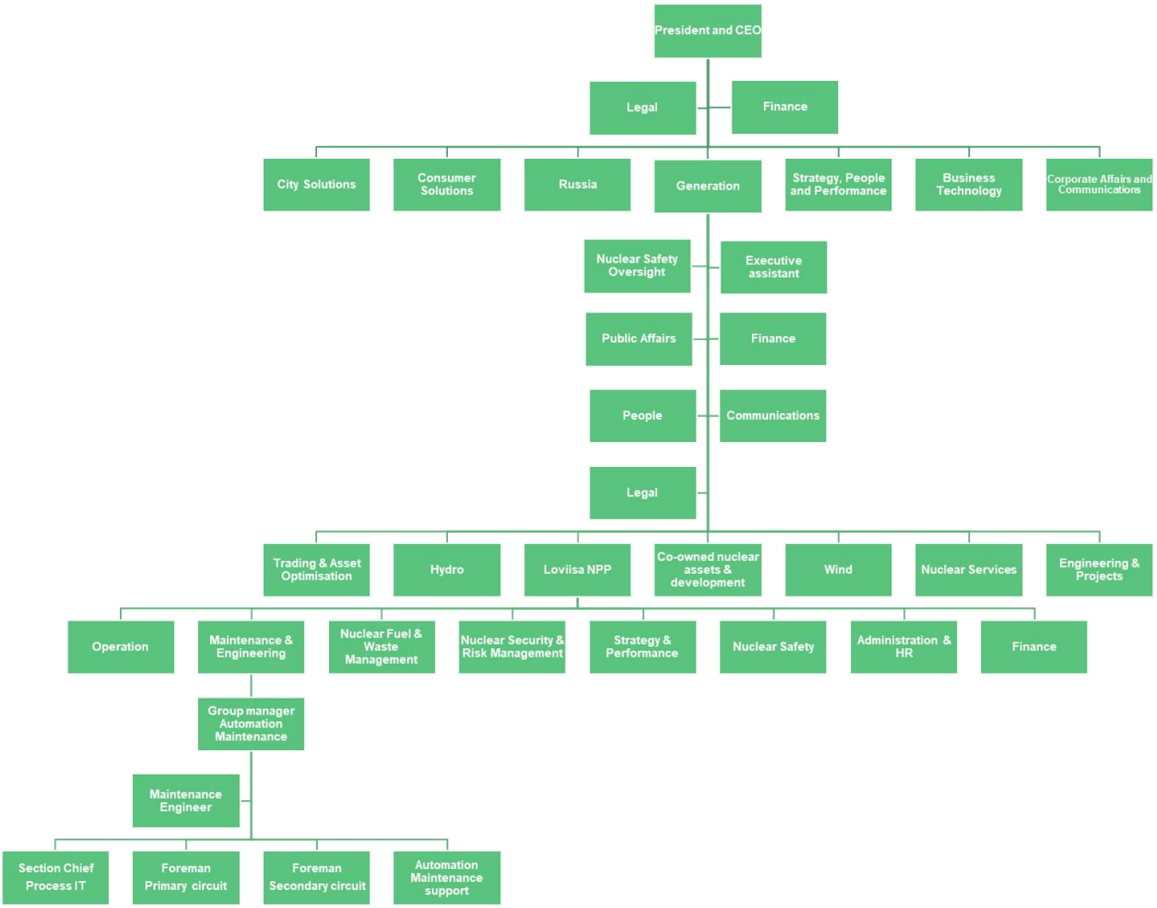

Figure 7. Organisation structure from the top to the Automation Maintenance group.

Below foremen, there is still one organisation level referred as technicians. The structure of this chart is previously described, and it can be observed that large hierarchical organisation with divisions and functions can have many levels.

This chapter focused on describing the basic structure of Loviisa NPP and particularly its organisation. Next, the theory of organisation structures and a specific organisation model are presented and examined.

3 ORGANISATION STRUCTURE AND MODELS

Organisation is a function that directs people to reach defined goals. More specifically organisation structure is a system of reporting and task relationships that coordinates, controls and motivates employees to reach organisation's goals. (Huczynski & Buchanan, 2001.) This section focuses on describing five organisation structures and models. Chosen organisation structures and models are functional structure, horizontal structure, matrix structure, informal structure and High Reliability Organisation (HRO) model.

3.1 Functional line organisation structure

Functional structure is constructed by grouping similar functions into one unit, group or team (University of Minnesota Libraries Publishing, 2017), for example Marketing unit, Production unit and Development unit. Each unit has its own manager and below there are specialists or workers. The example is shown in Figure 8.

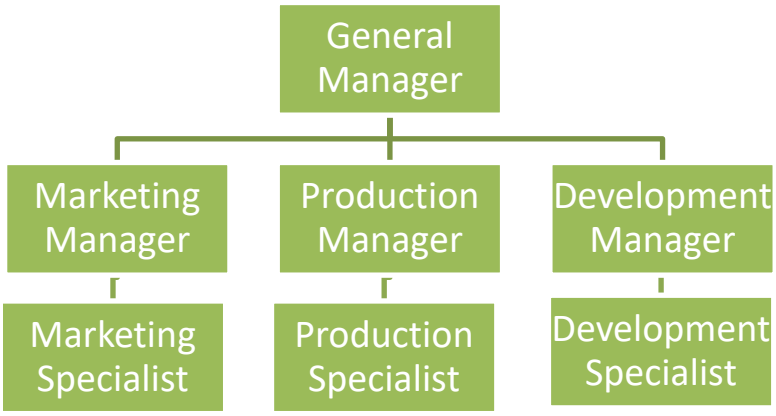

Figure 8. Functional organisation structure.

The functional organisation structure is ruled by chain of command. The higher the position is in the structure the more one has authority over resources and decision making. For example, in Figure 8 General manager has the most authority and has influence over every unit in the organisation and is on the top of chain of command. Below General manager level, there is the unit manager level such as marketing manager. Marketing manager has authority only over his or her unit and marketing manager reports to the General manager. Furthermore, below the second level, there is a marketing specialist

who has no authority over resources or decision making unless manager delegates these tasks to him or her. Marketing specialist is reporting to marketing manager who is one step higher in the line organisation. (Huczynski & Buchanan, 2001.)

In addition to this basic functional organisation structure there is a possibility to have support functions which are common when the company grows and becomes more complex. An example of the functional line organisation with a support function is shown in Figure 9. Organisations can have many support functions, for example Procurement function and senior advisors for managers.

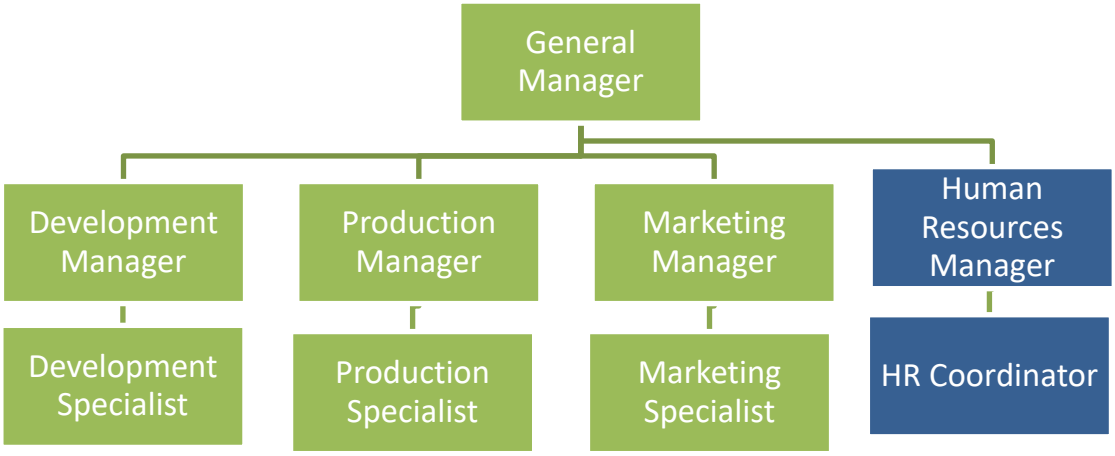

Figure 9. Functional line organisation with support function.

In this example the Human Recourses (HR) unit is not part of the core business area of the organisation but is a support function to it. HR unit has also a line relationship like the other units. HR manager is accountable of assisting other unit managers in human resource related topics. For example, HR Coordinator is assigned to help Production manager in recruiting for a new employee. The Human Resources unit has no authority over other units and can only advice the unit managers. For example, if deviation of a company's procedure is observed and informed by HR Coordinator and no corrective actions are made by counterpart unit manager, the HR Coordinator can report to HR manager, which reports to General manager who has the authority over other unit managers. The goal should be that there is no need to escalate deviations in the line

organisation and they would be corrected or prioritized appropriately when informed. (Huczynski & Buchanan, 2001.)

Only a small number of companies can be successful nowadays with a pure functional structure. One of the reasons is that divisional or functional silos prevent the coordination needed in changing competitional environment of a business. Organisations are finding ways to break these silos caused by functional structures. Communication between departments and divisions is strengthen with different horizontal linkage mechanisms. One common linkage mechanism is a cross functional manager who coordinates across different function departments to reach a common goal. Higher cross functional linkage can be achieved with matrix structure, which is described in the section 3.3. (Anand & Daft, 2007.)

3.2 Horizontal structure (process-based organisation)

Horizontal structure is a structure that aims to break down vertical silos and internal boundaries in order to make different functional units to work together horizontally. In Horizontal structure core processes are organised cross-functionally. Design principles include that organising is done by workflow processes rather than line tasks. Further, hierarchy is flattened and teams are used to manage processes. Process team leaders are assigned to lead internal team processes. In addition, expertise outside of the team is available if needed or wanted by the team. (Anand & Daft, 2007.)

Advantages of the structure are:

- Better communication and reduction in cycle time or better quality for a process.
- Employees working together in a team can develop wider perspective and flexible expertise.
- Better organisational learning is facilitated.
- Better responsiveness for new needs and regulations. (Anand & Daft, 2007.)

Disadvantages are:

- Dividing the organisation activities into process and non-process functions may be problematic.
- Possible non-process functions may feel neglected in the organisation.

- Teamwork might intervene with functional specialization, which is an advantage of functional organisation.
- Traditional functional departments may have territory conflicts with other parties. (Anand & Daft, 2007.)

One horizontal structure type is Business process management system which may result in several benefits for the organisations that choose to utilise it. Some benefits are:

- Faster process cycle time.
- Fewer errors when one function gives the process to another function department.
- More flexibility to alter the structure of current business processes. (Reijers, 2006.)

It is also noted that the implementation of Business process management system can be complex and time consuming. Business process management system focuses on supporting the adoption of processes that go through different functions in organisations. (Reijers, 2006.) A simple example of a business process is described in Figure 10 which flows through different functions in a functional organisation structure with horizontal process departments:

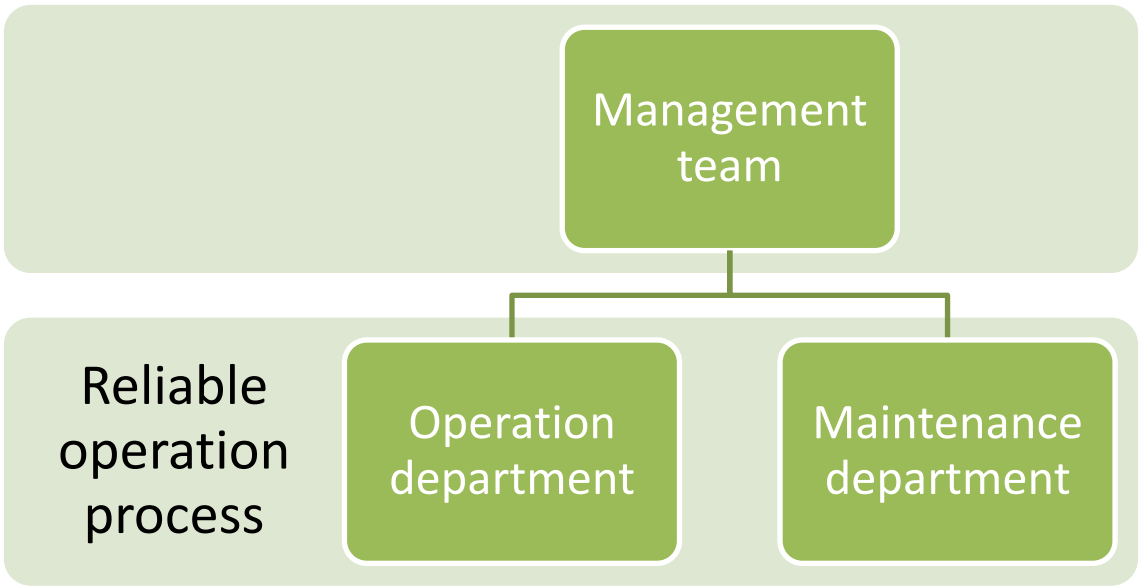

Figure 10. Reliable operation process in functional organisation.

For implementing the Business process management system, there are five elements which are crucial for the success of the implementation: structure, focus, measurement, ownership and customers. The study by Reijers (2006) concluded that the lack of these five elements, which are also factors to the definition "process orientation", affects indeed negatively to the implementation of Business process management system.

In the organisation structure point of view, the processes cannot be the only thing that defines the organisation structure. This is because functional expertise and the organisation's product management are still important functions to the organisation. It is also noted that not all activities in organisation can be defined as one of the processes, therefore cross-process functions would be mandatory in an organisation that is defined around processes. Lastly, it is stated that some planning and controlling activities are required on a higher stage compared to the processes. Consequently, the viable suggestion for most of the organisations is a multidimensional structure with ownership of a process being as the dominant dimension. (Vanhaverbeke & Torremans, 1999.)

In the process-based organisations top and middle management need to be in a different role than in a basic functionally structured organisation. Because of the different structural environment, the process-based organisation cannot be managed alone with the traditional strategy-structure style, in which top management has chosen a strategy and implements it in a clean top-down manner. In the process-based organisation the top and middle management need to be more supportive as stimulating entrepreneurship, spreading best practises and focus on dispersed knowledge throughout the organisation's units. (Vanhaverbeke & Torremans, 1999.)

3.3 Matrix structure

In matrix structure, employees which are reporting to unit managers like in functional structure are also reporting to another function's manager or project manager (University of Minnesota Libraries Publishing, 2017). In Figure 11, there is an example of a matrix structure:

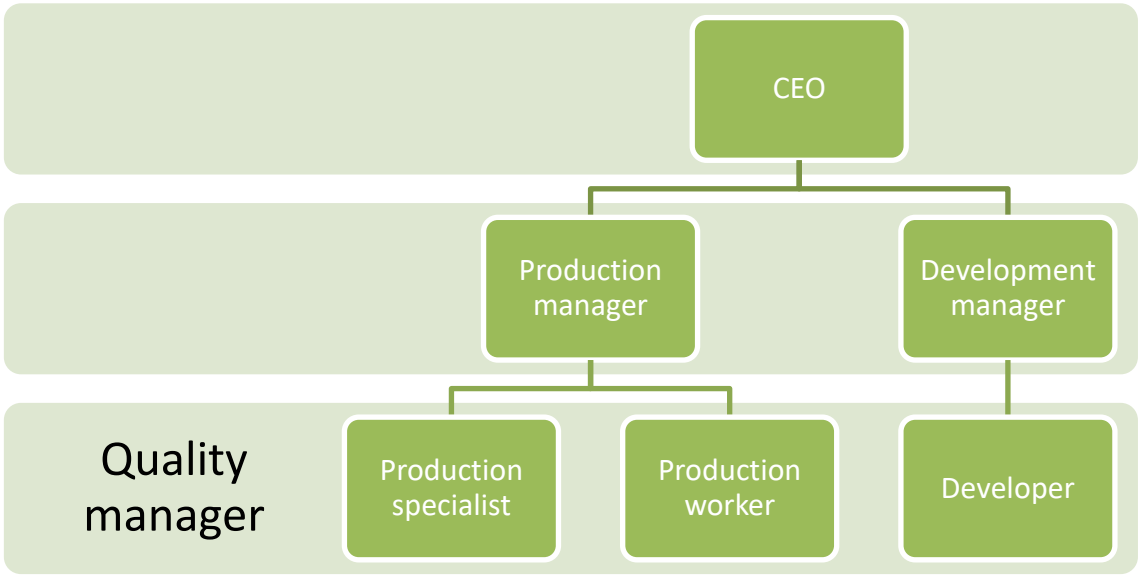

Figure 11. Example of a matrix structure.

Matrix structure provides the opportunity to increase communication between different functions. For example, in structure above (Figure 11), the cooperation between Production and Quality would have better environment to prosper due to mandatory reporting to Quality Manager and Production Manager. Research by Joyce (1986) has also shown that matrix structure improves the informal and formal communication within the organisation. On the other hand, matrix structure intervenes in the unity of command, because employee has two or more managers to report to. This can cause contradictions or even conflicts between managers. Also, reporting and coordinating come more complex because it differs from simple line organisation structure. (University of Minnesota Libraries Publishing, 2017.)

Stated advantages of matrix structure according to Huczynski & Buchanan (2001) are:

- Avoiding duplicated positions, since same employee can work on two different functions or projects.
- If one is a member of a project team, in addition to line organisation, one can focus better on the project with other project members.
- Providing function manager an opportunity to focus on line operation and the other manager is responsible of delivering its function.

Stated disadvantages are:

- Employee having two roles can cause conflict within different function managers.
- Employee's individual contribution may be harder to demonstrate because their working place changes between functions.
- There can be fewer promotion opportunities since movement is horizontal.

In their study, Bazigos and Harter (2016) did a survey which contained 4 000 workers in the United States of America. The findings were that benefits of matrix organisation were related to collaboration. On the other hand, the survey identified that the matrixed employees do not have clear vision about what is expected from them comparing to their non-matrixed colleagues. This is a major setback because clarity of expectations is crucial for building an engaged organisation that performs at a high level. (Bazigos & Harter, 2016.)

However, employees in a heavily matrixed organisation were more efficient in collaborating with co-workers than their less matrixed counterparts. Heavily matrixed employees had also more praise or recognition during the past seven days. In addition, their opinions counted more and their co-workers were more committed to do quality work. These findings support the fact that matrix organisation improves overall engagement of employees as well as collaboration and relationships among employees. But only a few of the heavily matrixed employees strongly agreed with the statement "I know what is expected of me at work" comparing to the result of 60 percent from the non-matrixed employees. This supports the commonly stated disadvantage of matrix organisations, which are the lack of clarity about expectations, responsibilities and thus who reports to whom. (Bazigos & Harter, 2016.)

Furthermore, employees in the matrixed organisations had more of their workdays spend in internal meetings and responding to co-workers' requests than their non-matrixed counterparts. This finding is not surprising in an environment where employees receive feedback and instructions from multiple managers and work with a range of employees to complete projects. (Bazigos & Harter, 2016.)

3.4 Informal structure

When organisation is deciding on organisation charts, types of authority and job descriptions, all relates to designing formal organisation. But to explain and understand the behaviour of employees in an organisation, it is also needed to acknowledge the informal organisation. Formal organisation charts tend to be overly static and do not show the dynamic changing of organisational life. Further, the descriptions of the formal relations do not show the informal social relations that are present among organisation's employees. (Huczynski & Buchanan, 2001.)

Stated by Selznick (1948) the informal organisation emerges in organisations because formal structures are inclined to reflect rational aspects regarding formal organisation, while lacking to take into account the non-rational dimensions of organisational behaviour. In Table 1, the differences between formal and informal organisation are shown.

Table 1. Comparison between formal and informal organisation (Gray & Starke, 1984).

	Formal organisation	**Informal organisation**
1) Structure		
a. origin	planned	spontaneous
b. rationale	rational	emotional
c. characteristics	stable	dynamic
2) position terminology	job	role
3) goals	profitability or service to society	member satisfaction
4) influence		
a. base	position	personality
b. type	authority	power
c. flow	top down	bottom up
5) control mechanism	threat of firing or demotion	physical or social sanction (norms)
6) communication		
a. channels	formal channels	grapevine
b. networks	well defined, follow formal lines	poorly defined, cut across regular channels
7) charting	organisation chart	sociogram
8) miscellaneous		
a. individuals included	all individual in work group	only those "acceptable"
b. interpersonal relations	prescribed by job description	arise spontaneously
c. leadership role	assigned by organisation	result of membership
d. basis for interaction	functional duties of position	personal characteristics status
e. basis for attachment	loyalty	cohesiveness

There are two main communication types in organisations, namely formal and informal communication. Formal communication can be a regular meeting or orders from a supervisor. Informal communication refers to communication that does not necessarily respect formal hierarchies or regulated channels. Informal communication can be social interactions in aisles or coffee breaks, for instance. (Costa & Matos, 2013.) In the Figure 12 and Figure 13, the examples of formal organisation and informal organisation are described respectively.

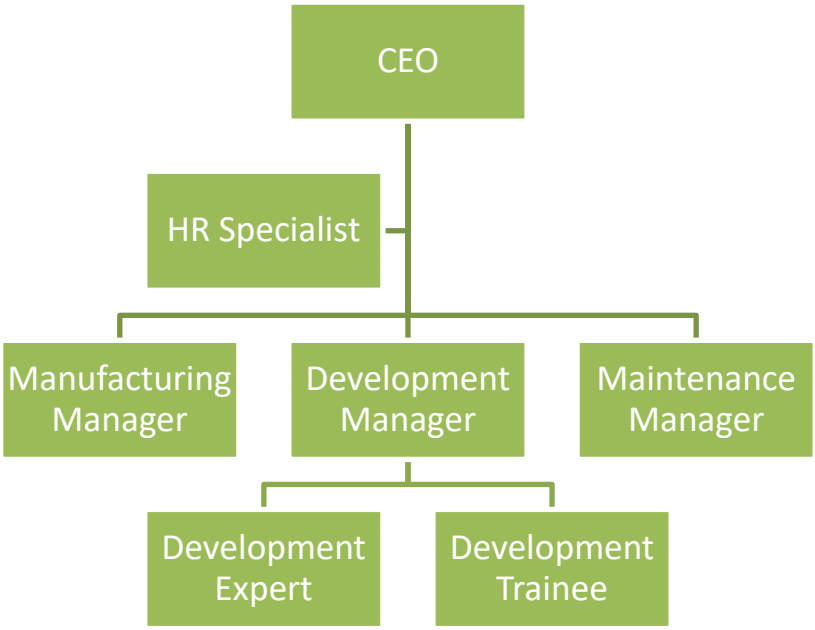

Figure 12. Formal organisation structure.

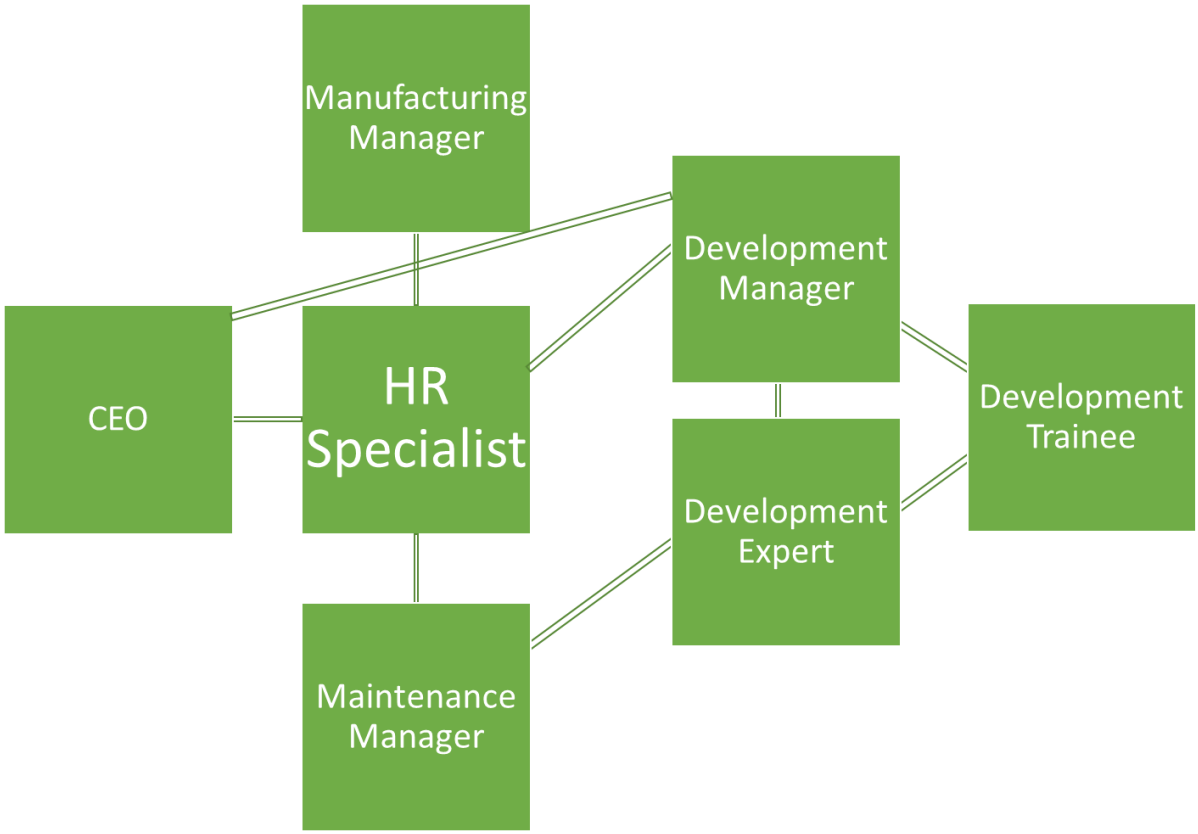

Figure 13. Informal organisation structure.

In the Figure 12, a formal hierarchical organisation is shown. An example could be an organisation that manufactures some components or products. Figure 13 shows the informal structure of the same organisation. It can be noted that HR Specialist has many ties to other employees and can be described as a central connector between CEO and managers. In the example above, the newest employee is Development Trainee and he/she has only ties to his/her team members. Development Expert and Maintenance Manager have a long history in the company and they interact a lot in coffee and lunch breaks.

In the previous example, the HR Specialist is a central connector that links employees in the informal network structure. The HR Specialist can provide solutions to difficult tasks or subjects by knowing the possible solution providers to the task. This also can increase productivity and therefore is a major benefit for organisation (Gable, Hu & Chen, 2012).

The relationship between formal and informal organisations can be consistent or inconsistent. When the formal and informal organisations are consistent and in sync, the

organisational goals and values are strengthened in the organisation. This is because the message from the formal and informal organisations is the same and employees can easily work towards common goals and values. (Gulati & Puranam, 2009.)

Furthermore, relating effect to the previous one is that individual does not have conflicts in his role when the formal and informal organisation are in sync. This leads to better performance because there are less negative conflicted role behaviours. Informal organisation may also have negative impacts in the organisation; for example, when the formal organisation is re-organised, the informal organisation might lag or refuse to adapt to the new formal organisation structure. This phenomenon is usually seen as unavoidable and can produce extra costs to the organisation. (Gulati & Puranam, 2009.)

3.5 High Reliability Organisations

Even though accidents are a part of human condition, in current society there are increased potential large-scale accidents and risks coming from the technologies such as aviation, new chemicals, genetically modified organisms, nuclear plants and other nuclear applications. These technologies that provide prosperity to the society have also potential to cause major and long-term accidents. In addition to understanding the technologies behind these technologies, we need to understand the organisations that implement, develop and sustain these technologies. Organisational factors are in major role in almost all accidents and therefore playing a huge role in preventing and understanding the accidents. (Leveson, Dulac, Marais & Carroll, 2009.)

First characteristic of High Reliability Organisations (henceforth HRO) is that the knowledge of the technical characteristics of operations is nearly perfect. The challenges begin to show up in complex technical systems when links and impacts between components cannot be fully predicted, planned, understood or guarded against. In other words, there is lack of full system understanding. The system should withstand this possible uncertainty to avoid accidents. (Leveson, et al., 2009.)

Second characteristics of HROs are stable technical processes and operation experience learning. The learning from operation experience might be harder in a case where new

system is applied and process changes are made. This is because the new system does not necessarily have operation history which would have provided the possibility for learning. The former characteristics has been particularly observed in low-level uncertainty systems and processes with stable technical environment. Moreover, these HRO characteristics are harder to implement in industries where frequent process changes are mandatory to achieve organisation's objectives. (Leveson, et al., 2009.)

3.5.1 How HROs differ from the rest

A research by Gentzel, Hessney, McDonnell & Thibert (2019) conducted in a cross-section of mostly heavy-asset industry organisations reveals some aspects of how HROs differ from the rest. Indeed, these organisations focus on the enablers of high reliability such as clear roles, strict processes and accountability systems as they do in new industry technologies. In addition to the previous factors, HROs focus on talent as putting premium on particular skills and focusing more in professional development. Finally, HROs create the structure of their organisations referring to how centralized the function and its accountabilities are. It is also noted that advanced technologies can deliver major improvements to the organisation, however in the end, it is the human factor that gives success. In Figure 14 there is described the three enablers for HRO. (Gentzel, et al., 2019.)

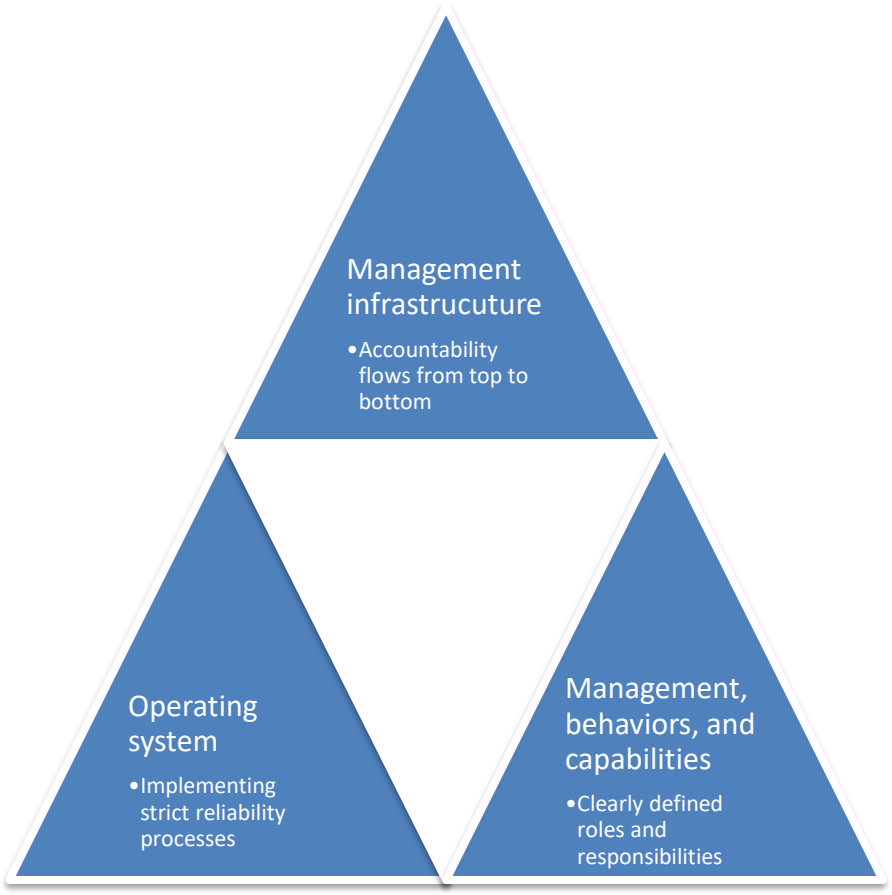

Figure 14. Three major enablers for HROs (Gentzel, et al., 2019).

In the research by Gentzel et al. (2019), there were eight organisations and they all followed strict reliability processes in their functions at all levels. They did stand out from the organisations which processes lacked specifics or were inconsistently followed. One example of HRO action was that they clearly defined the assets that are crucial to their operations. In addition, the deep understanding of the clearly defined list of assets is also considered in decision making. (Gentzel, et al., 2019.)

HROs also create equipment-reliability procedures and follow those by closely monitoring equipment health, following preventive-maintenance schedules and identifying issues as well as proactively solving them. Root cause problem solving can be also utilised to dig deeper and identify underlying problems and implement practical and holistic solutions. Reliability engineers use variety of tools, data sources, subject matter expertise and capabilities. Finally, HROs have strict systems for disseminating,

preserving, managing and updating their reliability knowledge, including reliability design standards and reliability analysis. (Gentzel, et al., 2019.)

Moreover, roles and responsibilities are defined clearly and understood thoroughly by leaders. Each employee of the organisation has a clear understanding of one's role in enforcing reliability. A leading pharmaceutical organisation rotates employees to give them understanding of other crucial roles in the organisation and how the other roles interact with the HRO. In addition, one characteristic for HRO is that accountability is set at the executive level and delegated down. (Gentzel, et al., 2019.)

Compensation is set relating to reliability specific outcomes and metrics. Indeed, clear reliability standards are set and communicated unambiguously. The standards are included in reliability metrics and they are visualized and distributed to the whole organisation. Outcomes, in turn, are discussed at all organisation levels. (Gentzel, et al., 2019.)

HROs consider that it requires more than just technical expertise to make a great reliability engineer. In order to have the best employees, HROs follow three practices: paying higher salaries than other organisations, require coordination and communication skills relevant to the role as a cross-functional problem solver, and provide clear career paths and options. Communication skills are specified as an ability to communicate up, down and across the organisation and gathering support and trust. (Gentzel, et al., 2019.)

Furthermore, HROs see that form follows function. HROs have many similarities but they vary widely in structure, referring to the specific challenges and characteristics of their industry. There are four models that vary along two dimensions: how centralized the accountability is and the strength of the central reliability function. In Figure 15, four different HRO models are shown. (Gentzel, et al., 2019.)

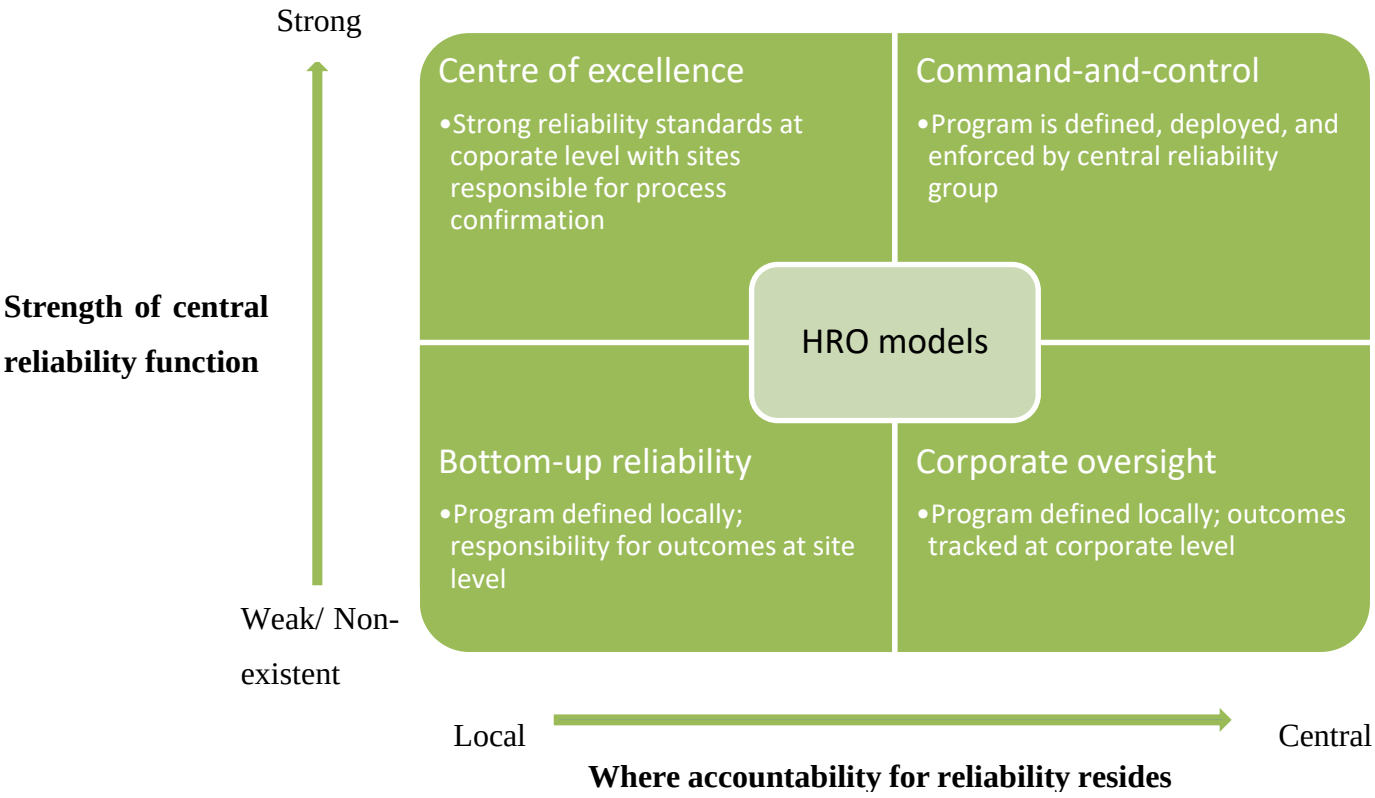

Figure 15. HRO models (Gentzel, et al., 2019).

The centre of excellence model has reliability standards at corporate level and each local site is responsible for implementation of the reliability standards. This model is suitable for organisations where assets are uniform and where processes have common characteristics. For instance, there can be a corporate level reliability analyst studying the big data of different sites and gives recommendations to the sites. (Gentzel, et al., 2019.)

Command-and-control model resides on corporate level central team for designing, implementing and enforcing the reliability standards. This model is suitable for organisations with high process-orientation and clear differences between operating facilities. However, this model requires strong oversight and this top-down approach ensures that all sites comply with the corporate level reliability standards. (Gentzel, et al., 2019.)

Bottom-up reliability model reside on local responsibility and definition of reliability standards. There can still be common corporate level metrics for all sites and the priority is to make them transparent in the whole organisation. (Gentzel, et al., 2019.)

In corporate oversight model the definition of reliability standards is done locally, but the corporate level has ultimate responsibility for outcomes. The corporate level usually develops key performance indicators for using enterprise wide. In turn, the local sites report these indicators to the corporate level. The corporate level also shares best practices among different sites. (Gentzel, et al., 2019.)

3.5.2 **How to become an HRO**

A study by Roberts and Bea (2001) gives in-depth practical characteristics for becoming an HRO. The three main factors to enhance reliability are:

- HROs seek to know and understand things that they do not yet know;
- HROs design their incentive system to recognize benefits of reliability and cost of failures;
- HROs communicate the big picture of the organisations goals and try to get whole organisation to communicate between employees to understand one's role in the big picture (Roberts & Bea, 2001).

In addition to the previous baseline factors, there are factors regarding to utilising failure simulations to train employees to be:

- aware of the possibility of accident;
- open minded in their thinking regarding to accidents and solutions;
- able to conduct appropriate responses, avoid decoys and develop dissociating strategies;
- authorized to fix problems;
- conscious of organisational commitment to prevent accidents (Roberts & Bea, 2001).

HROs use accident analysis to:

- communicate organisational awareness with accidents to enhance cultural values of safety;
- construct an organisational memory of what happened and why;

- evolve a science of accidents that can happen in that specific organisation;
- recognize parts of the systems that need to have redundancies (Roberts & Bea, 2001).

HROs also:

- use focus groups, employee surveys and interviews to ensure that the real goals of the organisation are the same as the publicly stated goals;
- review the incentive system on the point of view of balancing long-term unintended consequences or safety impacts with short-term financial goals;
- evolve reward measures of safety and integrates them as part of employee evaluation to make balance with the financial measures;
- evolve creative accounting techniques to count all the costs of having accidents and reserve a fund to avoiding them (Roberts & Bea, 2001).

In the management point of view HROs:

- encourage and reward managers to communicate openly with each other, particularly in situations that seem unusual, odd or problematic;
- enforces top management to tell stories about employees who saved the organisation from injury, losing major capital or reputation damage;
- create Incident Command Systems as a standing procedure with strict and well-known decision rules about when they are put in motion (Roberts & Bea, 2001).

3.5.3 **HROs in organisational culture point of view**

A study by Sutcliffe (2011) states that HROs concentrate on constructing an organisational culture, in which it is normal and frequent for employees to respectfully interact. Further, they promote an environment where employees interrelate mindfully so that they become aware of how one's work interacts with the other employees' work and the stated objectives of the organisation. Lastly, HROs initiate a set of procedures that makes it possible to track minor failures, avoid oversimplification of work events, maintain capabilities for resilience, remain sensitive to current operations and take use of rotating locations of expertise. (Sutcliffe, 2011.)

Respectful interaction is one of the key enablers in HROs. Employees in all organisations could come up with events where their own point of views come into dispute with a majority's view. Furthermore, it makes harder for employees to speak up about safety

hazards. To counterbalance this trend, it is crucial to create a frame of respect. In organisations where respect is a normal phenomenon, employees tend to communicate their analysis to other employees and thus tend to generate a shared analysis. If respectful interacting is absent, employees do not communicate about possible errors, since speaking up could damage their image or relations with their foreman or speaking will not affect anything. There are three moral norms regarding to respectful interaction:

- The first one is trust.
    - Employees respect the reports of others and are willing to base their actions and beliefs on them.
- Second is honest interaction.
    - Employees report their observations honestly so that others can use their observations to have valid impression.
- Third is self-respect.
    - Employees respect their own observations as they respect the observations of others in a way that they attempt to integrate their own observations into socially shared observation without despising their own observations or someone else's. (Sutcliffe, 2011.)

Studies show that when mindful interrelating takes place between aircraft carrier crews, they have fewer serious errors and accidents. Mindful interrelating is a social interaction in which employee's action contributes to a wider scale of shared action and in which employees acknowledge how one's action contributes to the bigger picture. (Weick & Roberts, 1993.) Mindful interrelating and respectful interaction generate shared action and shared interpretation and form together the relational basis for high reliability organising (Sutcliffe, 2011). A study by Vogus and Sutcliffe (2007) demonstrated that when higher levels of mindful interrelating and respectful interacting were monitored there were lower levels of patient falls and medical errors.

In addition to the mindful interrelation and respectful interacting, HROs have practices and attitudes that enables their employees to observe problems earlier as well as to act on them earlier (Weick, et al., 1999). Vulnerability to failures seems to be determined partly by extent to which processes and practices are aimed at:

- avoiding simplified assumptions about things,
- examining failures as a possibility to improve the system,

- being responsive to operations and its effects,
- locating and understanding expertise and creating procedures for decisions to transfer to these experts,
- evolving resilience to manage unexpected events (Sutcliffe, 2011).

The previous principles and associated practices are shown in Table 2.

Table 2. HROs organising principles and their practices (Vogus & Sutcliffe, 2007).

Concept	Definition	Illustrative practice
Care for failure	Operating with wariness of the possibility of unexpected failures that may compromise safety by engaging in preventive and proactive analysis and after-action reviews and discussion.	Before starting a job, employees identify activities that are crucial for the job to succeed. Reports to incoming employees include things to what look out for. Employees are motivated to express alternative opinions and to seek different perspectives.
Reluctance to simplify observations	Purposely questioning received wisdom and assumptions to create a more nuanced and complete picture of current situations.	Employees seek different perspectives and are motivated to express alternative opinions. Employees feel free to bring up issues and problems.
Sensitivity to operations	Ongoing information sharing and interaction about current organisational and human factors to create a uniform big picture of current situations so that minor adjustments can be made to prevent errors from piling up.	Employees interact frequently to build a common understanding of what is happening now. Employees have a good chart of organisation's different talents and skills. Employees have access to a range of resources whenever surprising events occur.
Commitment to resilience	Evolving capabilities to contain, cope with and bounce back from accidents that have already happened, before they worsen and cause more harm.	Employees constantly communicate about accidents, their prevention, and what could be learned from accidents. Employees constantly work to enhance their competence.
Respect to expertise	During intense times for example resolving a crisis, decision-making transfers to the employee with the most expertise with the problem type, ignoring authority or rank.	Employees acknowledge other's unique knowledge and skills and when problems come up use the unique skills of their work colleagues. When crisis occurs, employees swiftly pool their collective knowledge and attempt to resolve the crisis.

3.5.4 **HRO case study in large scale safety-critical projects**

A case study by Saunders, Gale & Sherry (2016) included nine projects in civil nuclear and civil aerospace industry sectors. The case study is organised around five features of an ideal High Reliability Organisation and the associated features of study by Saunders (2015) in Table 3. Within each section the study also highlighted the areas of difference and commonality between the two industry sectors, and the areas of dissonance and alignment with theories of HROs (Saunders, et al., 2016). Although the study is made to projects, it is still applicable to the case study Loviisa NPP because many processes can be defined as small repeatable projects and Loviisa NPP has also several different projects in addition to normal operation.

Table 3. Characteristics A1 to E4 about observable practices in "high-reliability project organising" (Saunders, 2015).

Core HRO characteristic	High reliability projects might:
Clarity of objectives (a)	1. Accelerate the formation of a dedicated project organisation with capable project leadership, and articulate a strong sense of mission in the team. 2. Make project objectives explicit, articulate them clearly and ensure that the trade-offs are understood. 3. Communicate the core events that must be precluded. 4. Acknowledge high levels of uncertainty early on. Accept work may start on the project with only minimum agreed high level objectives and many untested assumptions. 5. Ensure that project documentation, plans and team incentives are consistent with the declared project objectives.
Strong organisational culture (b)	1. Build on prior safety–critical project approaches. It may not be necessary to reinvent the wheel. Encourage learning in the project team by making time to share individuals' stories, lessons learnt, past project experiences. 2. Foster interconnections and relationships that span the project hierarchies and from which communities of practice may start to emerge. 3. Signal what is valued in the project by rewarding openness, knowledge sharing, multi-disciplinary problem solving and allow mistakes to be made and openly reported. 4. Afford areas of ignorance in the project the same importance as areas of certainty – discussing and debating them rather than closing them down 5. Delegate decision making (within pre-agreed decision rules), trust project team members and allow the sometimes quiet voice of the expert to be privileged above management orthodoxy. 6. Promote and reward project management capability and culture equally to the techno/professional one.
Presence of redundancy and slack (C)	1. Understand the underlying tempo and rhythm of the project. When do key decisions need to be made, and what is the real level of urgency? 2. Allow flexible and staged conformance to project processes, casting them off in emergency or urgent project situations. 3. Encourage the team to discuss and negotiate their way to a plan of action that is appropriate to the specific project situation. 4. Separate responsibility for technical delivery with schedule/cost delivery – Hold the two in constructive tension. 5. Make every effort to develop reflective project management practitioners who can think on their feet and not simply turn the handle of the project processes. 6. Advocate career progression that depends not only on delivery of project milestones but on demonstration of the "right" behaviours.
Mindfulness (D)	1. Avoid complacency. Engage continuously in "what if?" questions and worry constantly about "what could go wrong here in the project?" 2. Be attuned to small changes in projects that may be the precursors to bigger issues. 3. Avoid the tendency to jump to conclusions and make assumptions about the underlying causes of project problems 4. Maintain thorough knowledge of the project status, leading project indicators and talk to the experts on the ground. Treat intuition as importantly as hard project data. 5. Avoid over-rigid processes, routines and decision making and create space in the project for reflection, robust debate and even elements of anarchy.
Ability to prosper in the paradoxes (E)	1. Fight to retain flexibility in the proposed project solution even when this may increase project complexity in the short term. 2. Involve a more diverse coalition of project actors in project decision making even if this challenges the existing project consensus. 3. Acknowledge and articulate the paradoxes inherent in a high reliability project. 4. Learn that uncertainties in safety–critical projects cannot be eliminated; instead project managers must be able to dwell comfortably amongst this ambiguity.

The aim of the study by Saunders et al. (2016) was to empirically study whether the project managers have adopted the behaviours and practices above (Table 3) as a response to uncertainty of the project. The study is divided to headings by the core HRO characteristics.

3.5.5 **Clarity of objectives**

First feature to be examined was clarity of objectives. In both industry sectors the projects were organised as project groups in line with feature A1; the priority level and size of the

projects put this as a mandatory prerequisite. These groups were layered at multiple levels with core task delivery groups supplemented with many temporary task package specific groups, assigned with planning the best sequence of implementing services into different systems of a nuclear power plant or delivering and designing an aerospace sub-system. However, implanting the correct behaviours and values in all of the wide range of groups was not simple. One of the Nuclear programme managers stated that:

”There has been a great deal of effort put in to try to shape the structure and make it a normal delivery organisation. We have made some progress. We inherited from [Organisation X] a structure which was based on contracts. You can't do a project like this. It's not just about contracts. It's about the interfaces and gaps between the contracts that are the problem. It's taken us a long time to shift away from this, to say we are going to manage by areas.” (Saunders, et al., 2016.)

Moreover, several interviewees stated that there is a need to work with assumptions. Usually deep into the detailed design level, which supports the feature A4 in Table 3. An interviewee in nuclear test facilities developing project stated that:

“There are too many unknowns in the project. We are working up the delivery brief. The project has not been given a definitive ‘you shall do this, with this, at this time’. We are defining our own scope of delivery.” (Saunders, et al., 2016.)

Coping with this feature, the projects continued systematically and cautiously working with the assumptions and gathering all the professionals that were available to reduce the consequent hazards to project delivery and the uncertainties. The nuclear project’s area had a stronger acknowledgement of mission (feature A1), more sense of the compromises regarding to performance objectives (feature A2) and more sense of the core events that must be prevented from happening (feature A3). (Saunders, et al., 2016.)

Furthermore, there was an example when the delivery mechanism and objectives for a new Intermediate Level Waste storage facility were quickly changed which added a lot of uncertainty. The group worked a lot to define updated objectives and collect renewed acknowledgement of the mission in the project. The compromises in the project’s

priorities were communicated in an open manner with the purpose to encourage wanted project behaviours. (Saunders, et al., 2016.)

In civil aerospace the clarity of objectives did not infiltrate at all levels and areas of the projects as noted by one of the interviewees:

”the impact it has on uncertainty is that the people doing the work did not know that if the [new subsystem] had got on the aircraft we would have been stuck with it for a very long time, demolishing our salaries on a monthly basis” (Saunders, et al., 2016.)

One common factor to worry about among the civil aerospace interviewees was a challenge of keeping experts bonded to the project team and securing crucial resources. There were cases in which projects were started even though key resources were occupied on other projects and frequent employee changes and organisational restructuring effecting the projects’ acknowledgement of the mission. (Saunders, et al., 2016.)

3.5.6 **Strong organisational culture**

Second feature was strong organisational culture. Both industry sectors had evidence of learning (B1), visible incentives to reward knowledge sharing and openness (B3) and delegated decision making (B5). One civil nuclear interviewee stated that:

“At the end of day knowledge, skills, experience and wisdom are created in the people in the team. We learn. We become more competent individuals. So learning is shared with programme and stakeholders – done consciously.” (Saunders, et al., 2016.)

Further, civil aerospace interviewee said: “I've come from [x] programme and now work on [y] so I can share my experience with the new team. We do have lessons learnt logs and we typically do this at the end of each phase, so I am about to do this for the current phase. I will look at what we did on the [x] programme and did we carry any mistakes into the [y] programme and I'll put processes and procedures in place to make sure that doesn't happen again.” (Saunders, et al., 2016.)

Learning in both sectors was conscious. Indeed, learning was usually systematized and communicated to other employees to make it possible to act the lessons learned

throughout the project group. The learning was more formal in civil nuclear projects than in civil aerospace projects. Civil nuclear interviewees were keener to document learning from previous projects and bring up revised processes and lessons learnt logs. In civil aerospace projects the learning was based on informal communication. (Saunders, et al., 2016.)

Knowledge sharing and openness were evident in both sectors as one nuclear life extension project interviewee stated:

“Prioritisation of tasks is done with the safety case officer but it's not an authoritarian approach. It is more about openness with partners. We work better when we are more open. Whenever a question is raised, I try to make sure whoever has asked the question is satisfied with the answer.” (Saunders, et al., 2016.)

The intermediate level waste storage facility project interviewee shared more evidence of the desire to communicate what is valued in the project group and adopting more collaborative style of performing than adapting a culture of blame:

“For example, we have to hold ourselves to account for time periods and also hold the contractors to account. If either side is going to fail, we need to raise an early warning and work together with mutual trust and respect and cooperation to try to deliver a successful outcome. We need to be a much better client. This is totally alien to company culture.” (Saunders, et al., 2016.)

Both industry sectors’ abilities to cherish open culture seemed to depend on the willpower of project managers and their interpersonal skills, rather than being instructed by the central project organisation. The challenge for interviewees was how to nurture and encourage the open culture, within a current environment that would not want to:

“Admit to problems in capacity in the supply chain. So, approach is that we will just muddle through the project and project timescale will just start to slip to the right.” (statement by civil nuclear interviewee). (Saunders, et al., 2016.)

The core employees and employees outside the core project organisation, were usually authorized to make technical decisions and communicate (feature B5 delegated decision

making) in response to project uncertainty as stated by one the civil aerospace interviewees:

“We got the people who were involved at the time, who were the experts in the design, as the [component] suite is contracted out to external third parties on a design and make basis. They are the experts in this technology, not us.” (Saunders, et al., 2016.)

This favouring of technical experts was broadly seen across both industry area projects. Maybe because of difficulty of the technology, the project lead regularly looked for organisation’s key technical experts to gain knowledge about problems and better measuring of the risks regarding to different courses of action and for certainty that nothing has been missed. The risk of this dependency is that the knowledge in the organisation might vanish due to retirements. (Saunders, et al., 2016.)

Major deviation between the two industry sectors was in their desire to assign areas of ignorance in the project as the same significance as areas of certainty (feature B4). Several civil nuclear interviewees provided examples of attempts to bring out uncertainty, whereas this was absent in civil aerospace. Civil nuclear interviewees identified that first thing in solving uncertainty is to acknowledge where it resides. Possibly in the interfaces between technical experts or contracts, or in the hardiness of the core project schedule as told by one of the civil nuclear interviewees:

“What creates uncertainty is the failure to have a nice baselined project. The approach to the schedule here is not the approach that I am used to … Here a lot of it is coming from the Responsible Designer saying ‘here is what we think we are doing’. So no one knows how long it is going to take.” (Saunders, et al., 2016.)

The project managers who assigned the areas of ignorance the same or greater priority than the areas of certainty were ignored at the start of the project, but by demonstrating small accomplishments and working tightly together, they slowly triggered a prominent cultural change in the organisation. As related response from civil nuclear interviewee:

“Us as a small group of programme managers, we directly influenced the way the organisation is shaping itself and the level of rigour that is in the cost and the schedule plan.” (Saunders, et al., 2016.)

There was little evidence of raising interconnections that spanned project group’s hierarchies between the industry areas (feature B2) or giving incentive to project management equally regarding to capability and culture aspects comparing to technological and professional capability (feature B6). But there was acknowledgement from senior employees and core project teams that leading by example and encouraging the right way of working in early stages in the project was their responsibility. (Saunders, et al., 2016.)

3.5.7 **Presence of redundancy and slack**

Third feature area was presence of redundancy and slack (feature C). Both industry areas provided evidence of allowing staged and flexible conformance to project processes (feature C1). There was also evidence of encouraging the group to bargain their way to a case specific action plan (feature C3) and evolving reflective project management employees (feature C5). Flexible conformance of processes was observed at intermediate level waste storage facility, which had high levels of estimated uncertainty, because norms for the wanted work scope were absent. To handle this risk a decision was made to finish first estimates with higher level of uncertainty than mandated by the organisation. As noted by one of the civil nuclear interviewees:

“This is new. Systems are not configured to allow this, and approaches and procedures do not support it. So those are the challenges we face. Its obvious procedures don't work, systems do not support, so often flying on systems that are being pulled together as we go”. The Project Director had to doggedly argue the case with the project’s sponsors. (Saunders, et al., 2016.)

Interviewees in both industry sectors described cases of uncertainty where negotiation and communication lay deep in the analysis process (feature C3). This communication was multi-functional and often included customer and supply chain representatives. Accordingly, an interviewee from aerospace subsystem retrofit project stated:

“There are a couple of turning points in all of this. We had a workshop January this year and we've had various meetings but as things got closer, we were more confident that the design would pass qualification the urgency to get these things resolved rose. Some of the assumptions that were in the plan on day one needed to be revisited.” (Saunders, et al., 2016.)

Further evidence of feature C3 was shown in how the same project structured the roll-out of the retrofit components, constructing in redundancy to the process and therefore the whole system was more reliable. That made it possible for other airline operators to work at various retrofit frequencies and indicated a priority for a system level solution in oppose of only project focused solution. (Saunders, et al., 2016.)

Proof of the appearance of reflective employees (feature C5) was also found in both industry areas. Nevertheless, there were more indications of C5 among civil nuclear interviewees than others. One nuclear project management group reflected on how to execute a stronger contractor commitment in a contractually driven and conservative technical company. One of the civil nuclear interviewees provided an example:

“The idea of the ECI [Early Contractor Involvement] was a little bit organic. We did some work with the civils and that was the starter. As time went on it became clear that such an approach could have wider benefits, and this is how the strategy emerged. We started in civils and we have expanded this approach across all the disciplines, and I would look to take this approach into future projects. It's a very good tool. I probably wouldn't have thought of by myself — I am not sure any of us would in isolation.” (Saunders, et al., 2016.)

Previous findings indicate that in civil aerospace industry projects the high-level management of safety-critical processes are reflective and thoughtful, and not merely trained technicians. There were gaps between the two industry areas regarding to having acknowledge of the underlying rhythm and tempo of the project (feature C2) and for splitting schedule and cost delivery responsibility from technical delivery responsibility (feature C4). Nuclear projects showed less weight on tempo and time (feature C2) comparing to the rapid tempo of the aerospace development programmes. Surprisingly,

the operating nuclear power plant had rarely urgency in the project group working evenly for the next safety related case. Next statement by one of the aerospace interviewees describes the managing style regarding to project uncertainties which are dependent on their changing speed and nature:

“I guess it's about pace of change – my job changes by the hour as I'm trying to execute an engine build. This market stuff – does it change monthly? No. Does it change year to year? Probably so I review it more infrequently.” (Saunders, et al., 2016.)

Nuclear projects had clearer distinction of responsibility for schedule and cost delivery with technical delivery (feature C4). Surprisingly, this tension was not experienced as negative phenomenon, but as one of the nuclear project interviewees stated:

“There is tension in the relationship between the technical and the project management guys but this is positive and encouraged as it provides multiple perspectives and diversity of opinion.” (Saunders, et al., 2016.)

Additional supporting statements for this positive tension was noted by another nuclear project interviewee:

“This is a really good bunch of people I work with. They fight and they bicker but at the end of the day they all work very hard together, to get the project delivered.” (Saunders, et al., 2016.)

3.5.8 **Mindfulness**

Fourth studied feature was mindfulness. Indeed, there was evidence of all features regarding to mindfulness (features D1-D5) and there were also noticeable differences and commonalities between the two industry sectors. Both sectors had the need for not jumping into conclusions (feature D3) and keeping deep knowledge of the current status of the project (feature D4). Nevertheless, nuclear projects had stronger indication for avoiding complacency (feature D1) and being more adapted to small alternations (feature D2) as well as being more able to avoid over-rigid processes (feature D5). (Saunders, et al., 2016.)

Both industry sectors underlined the importance of understanding the things that they did not already know, and the benefits of asking simple questions to support uncovering the current status of issues and improve their confidence in the data sources available. Interviewees avoided to jump into conclusions and, instead, focused on the root causes of the issues as stated by one of the aerospace interviewees:

"The issue emerged on a routine maintenance check that was done. That flight was then grounded, and the units were stripped off and sent back to us for investigation. When we investigated it there was no fault found because it was as per the drawing but when we investigated further and took the cap off, we noticed a reservoir of liquid." (Saunders, et al., 2016.)

Interviewees also told that they made prioritising and judgement calls and acknowledging the moment when it was needed to escalate unsure cases to the senior management, as one of the nuclear project interviewees stated:

"My role is to quantify and put enough value and structure in place to deal with that risk, and questioning, probing the teams to make sure that they have taken these actions both in the commercial teams and in the technical teams. I do that through experience and asking the right questions in reviews." (Saunders, et al., 2016.)

Further, a civil aerospace interviewee stated that:

"Sometimes it is gutfeel and instinct, and you just get a feel for those are the three or four things I need to make sure are supported, coaxed along. The rest of the stuff will just happen." (Saunders, et al., 2016.)

Employees in both sectors used regular meetings, formal status reports, active questioning and combination of data and intuition based on broad experience of the process and handled detailed information and made decisions based on it. This, however, brings the risk of biased decision making when relying on intuition and the risk of not being experienced enough of unanticipated events. (Saunders, et al., 2016.)

No proof of complacency was found in nuclear projects (feature D1), but instead nuclear interviewees stated the following: "sniffing out uncertainty by feeling my way, and trying

to understand what I do not know" and "starting any project with a heightened level of nervousness, nervous energy almost, because you want to shake things and reduce the risks and uncertainties". The complacency in aerospace was more evident. For example, preliminary denial of issues was observed and suppliers were not called into questioning about hardiness of their schedules as told by one of the aerospace interviewees:

"We've used them [supplier Z] before … Out there we did have a similar situation, but we managed to sit down with [supplier Z], to get them to understand that they were a month behind, and they held programme from that point onwards. That gave us a false sense of security, in terms of this particular project." (Saunders, et al., 2016.)

Nuclear projects had more evidence for being adapted to small modifications in projects which could be a sign of more severe issues (feature D2). Positively, there were cases in both industry sectors where interviewees did monitor minor issues as potential signals of more severe issues and there were also cases where employees verified the case with technical experts before proceeding with the planned technical solution. According to an example provided by one of the nuclear project interviewees:

"Yes being candid with you we've had a couple of incidents on site recently, where something isn't quite right, not big issues but they are sort of indicators of things we need to nail quickly" (Saunders, et al., 2016.)

Unfortunately, mindfulness was more difficult to find in aerospace projects than other projects and mindfulness was endangered by schedule pressure regarding to given Entry to Service dates with customers, as one of the aerospace interviewees noted:

"So a few months back we had some issues. We had been running development engines, and on strip-down we found some debris in a certain part of the engine … At the time we put it down to development, may be during the manufacturing process some bits had been left behind. Subsequently we found a cracked [component] in another development engine, no debris and the crack was in a slightly different location, and we decided this was a manufacturing defect. We never really connected these two issues together." (Saunders, et al., 2016.)

In contrast, aerospace projects had more evidence of staying clear of over-rigid processes in projects (feature D5). Whereas, nuclear projects' processes and structures were rigid mainly due to regulatory aspects and the conservative nature of the industry. But there was one case of more flexibly structured project as stated by one of the nuclear project interviewees:

"We know what we want to do and when, but should new information emerge in the future, or the existing experimental plan is not delivering the data you want then you might have to revisit what you are doing, alter the plan, engage with people, do an independent review and get buy-in." (Saunders, et al., 2016.)

3.5.9 **Ability to prosper in the paradoxes**

Last feature discussed was the ability to prosper in the paradoxes. There were many indicators in both industry sectors for using more diverse group of employees in decision making (feature E2) and being capable to deal with uncertainty (feature E4). One example of using diverse group of employees in decision making was stated by one of the aerospace project interviewees:

"So they [our global physical logistics] came back with this information that we can't get through the bridges in Germany. So at that point we realised we had to engage with logistics professionals in Germany. So the [company Y] Germany team then engaged with some haulage companies out there to get them to look at and understand the options that we had." (Saunders, et al., 2016.)

Same type of strong indication was observed in dealing with uncertainty, as a nuclear project interviewee stated:

"I live with uncertainty. I know the [safety] cases are not lacking in uncertainty. I live with that — I am aware it is there, and I openly introduce margin into the safety cases. I try to get one big margin or contingency on top of the safety case. I am happy that that process is happening and that's how I can live with it." (Saunders, et al., 2016.)

Also, regarding a statement from one of the aerospace project interviewees:

“One of the key characteristics of the role is the ability to deal with ambiguity and uncertainty. The reality is that week in week out there will be uncertainty arising. My engineering background means I like to know everything that there is to know about something. Over time I've got more comfortable with dealing with uncertainty.” (Saunders, et al., 2016.)

The key factor for managing the uncertainty in a project was the capability to stabilize the tension between the demand to have progress on the project while being in perfect control of the required technical information. Numerous interviewees had learnt the hard way from previous experience that one should never assume anything, but to adopt a mindset with risk awareness and promote an attitude adapted to the uncertainty in the environment. The study evidenced a little of project management employees articulating and acknowledging the paradoxes in a high reliability project (feature E3). However, there were exceptions to this as stated in nuclear project interviewee’s statement:

“I'm pretty convinced now, that uncertainty is a perception. By putting risk and opportunities and assumptions around it, it becomes more concrete and although there is still probability around it. You have to try and put a process around it and try to quantify it. The quantification is itself uncertain because you've got probabilities around it. But at least it's a structured process.” (Saunders, et al., 2016.)

Lastly, there were more indications in nuclear projects than in aerospace projects for projects allowing more flexibility in decision making and trying to keep flexibility in the suggested project solution (feature E1). For example, following statement by nuclear project interviewee indicated prioritisation of finding the best delivery procedures over short-term progress of the project:

“So we have looked around and found out that Nuclear Decommissioning Authority have these NEC 3 based tools and contract management plans, but they have just not been brought to [Organisation A] site. So we have said we will be the pilot for [Organisation A]. We are building a contract management plan and will try to coach the contractor with our contract and our rules of engagement with people on the ground. We will walk them through what has to be delivered, what the constraints are, in first couple of weeks of the

contract. So we are trying to look forward as early in the contract as possible to try to anticipate issues, risks and uncertainties." (Saunders, et al., 2016.)

During the interviews, the study sensed that employees were struggling with paradox, as for example if the projects' delivery type was very different from previous projects it required adaption and flexibility in current project processes. One project director strived to be a leader who keeps the right path, even during difficult times and to manage unexpected issues. (Saunders, et al., 2016.)

The study provided indications for the adaption of high reliability features as a tool for managing uncertain circumstances. There were seen balancing in paradox, for example, if it would be better to test new engines by flying or taking more experiments. In addition, indications of avoiding inflexible processes, acting mindfully, approve constructive tensions, learning and interdisciplinary working were observed. (Saunders, et al., 2016.)

3.5.10 **Conclusions of the empirical study**

The HRO features were often at risk and the success of implementing these features dependent heavily on the strength of will and tenacity of a project manager. Unfortunately, these features did not often integrate in the organisation's memory and culture. Also, the features often emerged only as a response to case specific issues and not as a feature that is planned from day one. Further, the features were often mandated by senior management instead of occurring at the operational level of the project. The study also identified that senior management should improve awareness regarding to the features of high reliability. (Saunders, et al., 2016.)

High reliability features were often implemented locally in a specific organisation function and were difficult to spread the features beyond core project group. There was also observed structural factors intervening on project managers' mission to implement high reliability features such as public sector related nature, complex ownership structures and short-term incentive programs in nuclear industry that can lure organisations to adopt potentially harmful short-term financially focused solutions.

In addition, Oedewald & Gotcheva (2015) state that it is hard to delegate decision making to the appropriate level as the structure might be fragmented with wide network of contractors and subcontractors and some without the appropriate expertise in nuclear industry. In aerospace projects the risk of reactive acts on emerging issues, organisational culture of only putting out fires and suboptimal resource allocation are due to tight deadlines by the customer (Saunders, et al., 2016).

This study provides evidence for using high reliability features to manage project uncertainty. But the relation between adoption of high reliability features in projects and safer, more cost efficient and more timely delivery of projects remains unproven. (Saunders, et al., 2016.)

The theory and empirical studies of organisation structures and HROs provides the foundation for the identification of the gaps in the Loviisa NPP's performance. In next chapter, the observations of Loviisa NPP performance by external and internal parties are processed and compared to the HRO characteristics examined in this chapter.

4 EVALUATIONS CONDUCTED TO LOVIISA NPP

4.1 Evaluations by Corrective Action Program group

Corrective action program group (henceforth CAP-group) is an internal group in Loviisa NPP which includes experts focusing on safety, quality and performance aspects. In addition, the group's purpose is to monitor performance of processes and their interfaces. CAP-group's objectives are to observe actions from different areas of the organisation and recognize similarities that would not be noticed if merely focusing on a single area. (Ropponen, 2017.) The evaluations are done by comparison to the best practices and supporting the Loviisa NPP's continuous improvement process.

CAP-group makes report annually which includes:

- the most significant and repeated observations,
- comments from CAP-group,
- assessment of safety culture,
- development ideas by overall assessment (Ropponen, 2017).

Annual report of year 2016 concluded potential areas for improvement in:

- corrective action follow-up,
- tidiness and clear management expectations,
- balanced prioritizing of observations by internal and external parties,
    - prioritization is focused on resolving external observations (Ropponen & Kivirinta, 2017).

Positive observation was made about safety culture area "safety is learning driven" and for example reporting culture was improved and considered to be at high level (Ropponen & Kivirinta, 2017).

Annual report of the year 2017 included same observations than in the year 2016. Positive observation was that tidiness and order were included in the power plant's main themes, but there was still some improvement potential in the clear requirements of tidiness level at the power plant. Although, there were clear improvement in the management's expectations with better clarification and communication. (CAP-group, 2018.)

Loviisa NPP has open and healthy working environment and procedures for handling things are available but there is some improvement opportunities for reaching the next level in safety culture (CAP-group, 2018).

In the year 2018 annual report, the identified potential improvement areas were:

- tidiness and clear standards for tidiness,
- quality of instructions,
- following instructions,
- user experience in instruction system,
- attention on human factors and Human Performance tools,
- executing pre and post job briefings as instructed (CAP-group, 2019).

Identified strengths were:

- power plant's main themes including tidiness and order was implemented,
- standards for Nuclear professional was implemented as described in Figure 16,
- improvement in transparent decision making,
- every superior participated to Open Leadership coaching,
- supervisors go frequently to interactive safety walks,
- open work environment,
- efforts on reducing organisational silos,
- development of main processes is almost completed,
- increased amount of observations by personnel,
- improved operation experience learning (CAP-group, 2019).

Figure 16. Nuclear Professional at Loviisa NPP (Fortum Power and Heat Oy, 2019).

4.2 Safety culture evaluation by Fortum Power and Heat Oy

In year 2019, Loviisa NPP ordered a safety culture evaluation from Finnish Institute of Occupational Health. Evaluation's frame of refence was IAEA's safety culture characteristics, where the characteristics of safety culture are:

- Safety is a clearly recognized value.
- Leadership for safety is clear.
- Accountability for safety is clear.
- Safety is integrated into all activities.
- Safety is learning driven. (International Atomic Energy Agency, 2009.)

The evaluation did not find deviations from requirements, but potential improvement areas were found (Work group, 2019).

4.2.1 Safety is a clearly recognized value

According to IAEA's characteristic "the safety is clearly recognized value", it should be observed in a manner as follows:

- The importance of safety is observed in documentation, communication and decision making.

- Safety is the first priority when distributing and focusing resources.
- The importance of safety is visible in the business planning.
- Individuals are convinced about the fact that safety and generation go hand in hand.
- Proactive and long-term approach to safety is visible in the decision making
- Safety conscious behavior is approved and encouraged in the workplace (officially and unofficially). (International Atomic Energy Agency, 2009.)

The importance of safety was observed in Loviisa NPP's documentation in several ways. Fortum's Nuclear operations have a safety and quality policy (Fortum Power and Heat Oy, 2017), safety culture program (Leinonen, 2017), and several other documents parsing safety characteristics and building commitment to safety as a Nuclear professional at Loviisa Nuclear Power Plant (Fortum Power and Heat Oy, 2019).

Safety is also raised in the management's long-term strategy, which is defined as a goal for safe, reliable and profitable electricity generation and at the end of operation a safe and cost-efficient decommissioning and final disposal of nuclear fuel. The strategy also highlights openness, communication, trust and operating by the instructions and procedures. In Figure 17 is the strategy of Loviisa NPP until the end of operating licenses. (Loviisa NPP's management team, 2018.)

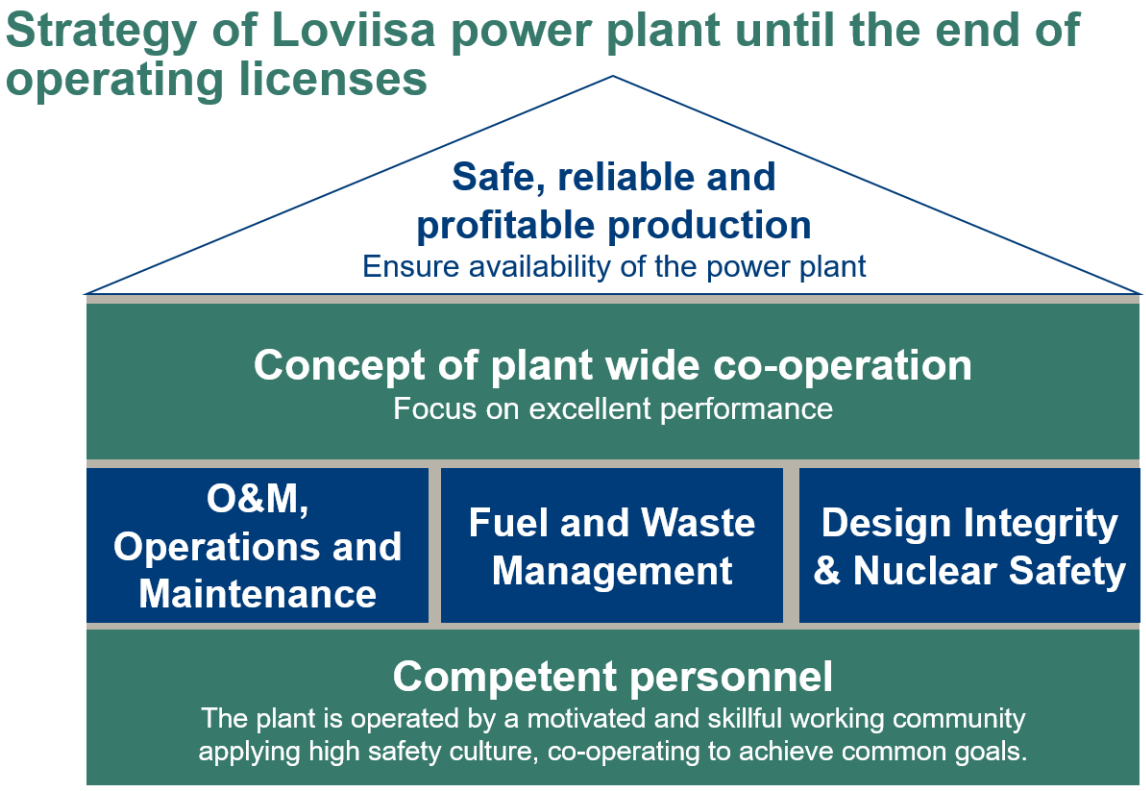

Figure 17. Strategy of Loviisa power plant until the end of operating licenses (Loviisa NPP's management team, 2018).

Loviisa NPP's management guide states that management sets goals, instructions and articles regarding to safety, supervises and secures resources and guides safety culture with own behaviour (Katajala, et al., 2019). In the interviews conducted to the Loviisa NPP's management, it was noted that in year 2017 management's expectations were clarified and their communication was improved. The management set clear and ambitious safety goals "Big Rocks" (oil leaks, Human Performance and tidiness and order) more visible. At the same time, it was identified that before, the so-called Big Rocks were overwhelmed by several small goals. In Figure 18 below, the Loviisa NPP's Big Rocks from years 2019 and 2020 are described. Nevertheless, OSART's assessment in year 2018 reports that the Big Rocks have still areas of improvement. (Work group, 2019.)

Figure 18. Loviisa NPP's main safety themes (Big Rocks).

STUK's inspection report (Oedewald, 2018) states that Loviisa NPP's management team is using "strategy house" as shown in Figure 17 to parse Fortum's strategy's main elements to Loviisa NPP's goals. The inspectors did not observe a clear image of how the management directs or supports operations based on this common snapshot in the strategy house. In the management interviews the strategy house's importance and competent personnel's importance as a foundation of the strategy house was highlighted. (Work group, 2019.)

It was identified at all organisation levels that safety culture has developed a lot and personnel can analytically bring up safety culture related development needs. The year 2018 safety culture survey answers indicated that safety culture areas are on average at a good level. Few interviewees noted that safety culture is shown as particularly concrete in Loviisa NPP and more abstract in other Fortum's nuclear related operations. (Work group, 2019.)

However, STUK's inspection report Oedewald (2018) indicates that there is no evidence that information analysed by a specialist regarding to safety culture would be processed efficiently in the management team and that management team would initiate analysis to safety culture's improvement at the current state. STUK has set a demand that license

holder has to analyse what are the procedures of answering CAP-group's identified safety culture development needs and what are the license holder's concrete goals and how their effectiveness can be proven. License holder has to develop assessments regarding to safety culture's current status in a manner that conclusions for safety culture's strengths and weaknesses have been presented clearly and consistently based on the observations. (Work group, 2019.)

Conclusion of "Safety is a clearly recognized value" is that safety aspects are recognized in documentation and communication in Loviisa NPP and in other Fortum's nuclear operations. Safety aspects are also noted in the safety and quality policy and in the strategy. The meaning of safety is understood extensively among personnel and safety is largely a built-in function in organisation's thinking. Further, the significance of safety is communicated through several channels and safety orientation, anticipation and perseverance are present in decision making. Altogether, the primacy of safety has been successfully developed all the time and it is recognized at all organisation levels. (Work group, 2019.)

Development areas from the evaluation:

- In practice, there are occasionally conflicts and inconsistencies that safety as a recognized value is not fully fulfilled. For example, intervening to risks and grievances, relationship between safety and generation and brining actions all the way to concrete actions. The management team and supervisors must strengthen safety as a value in everyday work.
- Management's expectations and goals are not fully communicated, or personnel is not always aware of them. Goals and expectations need to be communicated clearly and in timely manner. Thus, proactive communication should be developed.
- There is a lack of resources in some areas of experience. Recourse needs should be assessed with the personnel. (Work group, 2019.)

4.2.2 **Leadership for safety is clear**

By IAEA's definition the characteristic "leadership for safety is clear" should be observed as follows:

- Top management is truly committed to safety.
- Commitment to safety is shown in all organisation levels.
- Management's visibility and participation is an indication of commitment to safety activities.
- Leadership skills are systematically improved.
- Management confirms that personnel's qualifications are sufficient.
- Management encourages personnel to participate actively to improve safety.
- Safety is considered in change management instructions and procedures.
- Management tries constantly to increase openness and good information flow in whole organisation.
- Relationship between management and personnel is based on trust.
- Management is capable of solving conflicts if needed. (International Atomic Energy Agency, 2009.)

As a conclusion of "leadership for safety is clear", it can be noted that leadership for safety is highlighted in Loviisa NPP and in other nuclear related operations. Management is committed to safety and personnel is encouraged to participate in developing safety in several different ways. Safety's importance is highlighted with frequent communication and there is a climate of trust in the organisation. Management team and supervisors are considered being easily accessible. Work supervisor's working procedures are proactive, confirmatory and participatory. (Work group, 2019.)

Development areas for the safety culture characteristic:

- Line management's ownership and performing in safety matters should be strengthen at all organisation levels (corrective action implementing support and confirmation, systematic inclusion of personnel and reinforcing line managements' support for operation experience function).
- Personnel still feels that plant management should be more visible in the field. Personnel's experience about management's participation and inclusion should be strengthen, for example with regular events such as workshops in which main target would be collecting personnel's experiences interactively and jointly brainstorming for solutions.
- There should be more active communication to personnel about management's and supervisor's safety walks and other actions related to visibility.
- Assessment noted some indications of improvement areas in the management's understanding of causes regarding the operation challenges or the available information is not necessarily utilised in a timely manner nor sufficiently enough. Cooperation and inclusive development should be enhanced among

personnel. Indeed, personnel has practical knowledge and ability for analytical observation which should be utilised. At the corporate level, there should be a verification that also elsewhere in the organisation, there is sufficient understanding of nuclear operations' special characteristics and needs in aging power plant.

- Timelines of actions should be noted more, and assessment of effectiveness should be improved further
- More proactivity in aging power plant's operation. Personnel was concerned of different factors regarding to aging of the power plant like maintenance intervals and predictive maintenance's adequacy, availability of spare parts, device heterogeneity, challenges between human and machine interaction, personnel changes and identifying skill demands at an old plant, working conditions and modernizations. Licence holder should comprehensively, proactively and systematically asses risks regarding to aging power plant's operation together with personnel and make a plan for risk management.
- Loviisa NPP does not fully use a systematic procedure for analysing training needs and planning, developing, implementing and assessing a training program. Indeed, development of knowledge management is currently a work-in-progress in Loviisa NPP and it is still needed to be invested in since knowledge management has a significant impact for aging power plants operating conditions. In terms of knowledge management, transferring and verifying knowledge must be considered in the case of possible outsourcing.
- Supervisors should consistently and systematically intervene to unsafe procedures but also to deviations in the work environment. Work supervision level might benefit from training regarding to the immediate supervisor's rights and duties to intervene to unsafe actions and further to train for challenging intervening scenarios. (Work group, 2019.)

These development areas also relate to the next characteristic "accountability for safety is clear" (Work group, 2019).

4.2.3 **Accountability for safety is clear**

The following areas are included in characteristic "accountability for safety is clear":

- Appropriate cooperation with regulators and following operation license terms responsibly to ensure continuation of operations.
- Roles and responsibilities are clearly defined and understood.
- Regulations and instructions are strictly respected.
- Management delegates responsibilities and authority related to a task.

- Whole personnel are committed to safety in all organisation levels. (International Atomic Energy Agency, 2009.)

In conclusion, "accountability for safety is clear", namely cooperation with regulator, is at good level. The cooperation relationship with STUK is considered good and open. Regulator's role in ensuring safety was well understood. Further, there was a common interest for ensuring safety between Loviisa NPP and STUK. Roles and responsibilities in the organisation were clearly described, defined and understood. In addition, instructions are known and obeyed. Safety and obeying related instructions were central and natural part of the operations for the personnel. (Work group, 2019.)

4.2.4 **Safety is integrated into all activities**

The following areas are included in characteristic "safety is integrated into all activities":

- An atmosphere of trust prevails in the whole organisation.
- All sorts of safety areas like plant safety, work safety, environmental safety and security arrangements are taken into account in the operation.
- The quality of documents and instructions are in high level.
- Operation processes quality from planning to implementation and reviewing are in high level.
- Personnel has necessary information and understanding about instructions and procedures related to a job.
- Factors regarding to work motivation and work happiness are taken into account.
- Working environments are good and schedule pressures, workload and stress are taken into consideration.
- Different units and profession groups work in harmony and cooperate.
- Good tidiness and order are a sign of attempting to reach excellence. (Work group, 2019.)

In conclusion, it is observed that safety is understood comprehensively including different safety areas. There has been a lot of attention to development of instruction usability and timeliness. Instruction system is broad, comprehensive and mainly at a good level. Tidiness and order has been in high attention in Loviisa NPP, but there is still some improvement possibilities. (Work group, 2019.)

Cooperation between different organisations has been developed and actions for reducing siloing has been made. Loviisa NPP has developed procedures for describing operation processes. Loviisa NPP has also pre and post job briefing procedure which is central and concrete tool for ensuring and foreseeing safety in complex working environment. (Work group, 2019.)

Development areas in "safety is integrated into all activities" are:

- Instruction quality, usability and findability must be improved further and conflicts between instructions should be fixed. Indeed, the risk of over instructing such as too specific or insubstantial instructing, which can have negative impact on safety, should be scrutinized. Further, personnel's know-how should be better utilised when making instructions. Work order quality and accuracy of content should be in higher attention.
- Cooperation and common development with different units should be increased. This can develop the forming of the big picture in the complex power plant environment and on the other hand decrease organisational siloing.
- The realization of pre and post job briefings needs to be followed and confirmed accordingly.
- Planning and procurement unit's cooperation with power plant needs to be increased and there is need to ensure a sufficient understanding and practical knowledge about aging power plant's operation environment for planning and procurement functions. Planning personnel requirements to make enough visits to the target area to ensure quality; during planning process it is beneficial to cooperate with target area's personnel.
- The level of tidiness and order should be monitored and improved systematically and consistently. Sufficient performance level of the outsourced functions regarding to tidiness and order needs to be carefully looked after. Work environments, equipment ergonomics and usability need to be improved when possible.
- Maintenance of resources needs to be assessed and ensured regarding to needed preventive maintenance due to power plant's aging.
- Monitoring and management work wellbeing need to be improved further and tools for supporting personal coping management need to be available at all organisation levels.
- Human factors management needs to be processed comprehensively and not controlled by loose factors or work procedures. Comprehensive knowledge regarding to human factors needs to be improved as an acknowledged and systematic process. (Work group, 2019.)

4.2.5 **Safety is learning driven**

The following areas are included in characteristic “safety is learning driven”:

- Open environment for questions and ideas prevails at all levels of the organisation.
- Open reporting about deviations and mistakes are encouraged in the organisation.
- Making use of internal and external evaluations and self-assessments in improving the performance.
- Internal and external operation experiences are used in learning.
- Operation experience learning is enhanced by analysing reasons for deviations, planning and implementing corrective actions and monitoring effectiveness of actions.
- Safety indicators are defined, followed and acted upon.
- Personnel competences are improved systematically. (Work group, 2019)

In conclusion, “safety is learning driven” comprehends that reporting culture is open and in good condition. Namely, inquiring and conservational atmosphere prevail in the organisation. Personnel is encouraged to question and bring forward concerns and development ideas. Moreover, personnel has low threshold to contact supervisor in uncertain situations. (Work group, 2019.)

Operation experience function and assessment of effectiveness have developed during the recent years, nevertheless several personnel changes are creating challenges. Corrective Action Program was initiated to create the big picture about power plant’s current state, which is a remarkable development step in terms of organisational learning. (Work group, 2019.)

Development areas in “safety is learning driven”:

- Implementation of actions based on observation reports and personnel’s development ideas needs more attention. Further, line management needs to take responsibility of the realisation follow-up.
- Personnel should be involved more in planning the actions as well as choosing them in order to be able to take actions that are working and effective in practice.

- Management needs to give strong support for operation experience function and give adequate resources for it.
- Comprehensive knowledge and management of human factors needs to be increased at all organisation levels.
- Loviisa NPP needs to develop clear and documentation-oriented benchmark procedures. (Work group, 2019.)

4.2.6 Conclusions of the safety culture study

Licence holder's safety culture and safety culture management fulfil the requirements of the regulations and regulator's guides. Regarding to the study, the safety culture in Loviisa NPP is strong and constantly developing. During the past operating license management system and procedures, there has been systematic improvement and new procedures have been introduced. Development work done during the past operation license is clearly observed and the results are seen in concrete improvements. For example, in instruction development and pre and post job briefing procedures and in personnel's attitudes towards safety. (Work group, 2019.)

Although licence holder's safety culture and its management fulfil the requirements in this evaluation, it still has to develop, by the continuous improvement principle, its safety culture and its management capabilities during the next operation license period. Development must be goal-oriented, planned and coordinated thus that development function entity stays in control. Main improvement areas are improving inclusive development culture and management, taking into account the challenges of the ageing power plant, keeping the knowledge level at appropriate level and improving operation experience function. (Work group, 2019.)

4.3 Safety culture questionnaire by Loviisa NPP

Safety culture questionnaires have been conducted in Loviisa NPP in years 2015, 2016 and early 2019. The questionnaires were answered by internal and external employees. During the years 2015 and 2019, the response rate increased from 69,5 % to 75,3 % (Päivärinta, 2019).

The questionnaire included five safety culture areas defined by International Atomic Energy Agency (2009):

- Safety is a clearly recognised value.
- Leadership for safety is clear.
- Accountability for safety is clear.
- Safety is integrated into all activities.
- Safety is learning driven.

In Table 4 are the results of different safety culture areas in Loviisa NPP on the scale of one to five, in which the higher is the better.

Table 4. Results of the year 2019 safety culture questionnaire (Päivärinta, 2019).

Safety culture area	**Result 2019**	**Result 2016**
Safety is a clearly recognized value	4,06	3,96
Leadership for safety is clear	3,82	3,73
Accountability for safety is clear	4,08	3,95
Safety is integrated into all activities	3,62	3,62
Safety is learning driven	3,84	3,75

It can be observed that the strength of different areas is increased in all areas expect "Safety is integrated into all activities" in which the result is the same as in year 2016. It is observed that leadership has developed to the right direction and in line with Fortum's strategy in which supervisor guides and coaches personnel. (Päivärinta, 2019.)

The conclusion of the questionnaire is that organisation's culture supports good safety culture. Things are discussed openly and own behaviour is reflected. At the same time, development proposals and solutions are considered and brought up. Instructions, organised training and current procedures maintain to be important. Reoccurring observations from the last year were that instructions, processes and procedures are kept important, but at the same time they are occasionally found difficult and complex by

personnel. Things related to leadership and supervisory work are also repeated subjects and answers indicate that supervisors should lead more by example and being present in daily work. (Päivärinta, 2019.)

4.4 Evaluation by World Association of Nuclear Operators (WANO)

In year 2019, a WANO peer review was conducted in Loviisa NPP. The purpose of the review was to determine strengths and areas of improvement as well as to support the Loviisa NPP's management and personnel in their improvement process. The evaluation is done in reference to worldwide best practices. (World Association of Nuclear Operators, 2019.)

Identified potential improvement areas were found in following areas:

- risk identification,
- questioning attitude,
- threshold for deficiencies identification,
- problem identification and resolution,
- work processes,
- leadership accountability (World Association of Nuclear Operators, 2019).

Identified strengths were in:

- chemistry,
- work management,
- respectful work environment,
- environment for raising concerns,
- using virtual reality, augmented reality and 360-degree imaging for training purposes (World Association of Nuclear Operators, 2019).

4.5 Evaluations by IAEA's Operational Safety Review Team (OSART)

In year 2018, there was an evaluation conducted by IAEA's Operational Safety Review Team. OSART evaluation's goal is to improve operational safety by evaluating safety performance using IAEA's safety standards and proposing improvement possibilities when appropriate (International Atomic Energy Agency, 2018).

The evaluation team observed that the Loviisa NPP has made safety improvements proactively during the recent years such as updates for safety systems and automation modifications. It was also observed that employees at the plant are transparent, open and receptive to proposals to develop operational safety in the power plant. (International Atomic Energy Agency, 2018.)

Observed good practices were:

- The power plant constructed a process to improve and test system modifications and updates early.
- Loviisa NPP automatically calculates leak rate tests of containment.
- The power plant has implemented a key system to effectively control access to different areas of the power plant. (International Atomic Energy Agency, 2018.)

Proposals for possible improvement of operational safety were:

- The power plant should develop its maintenance procedures and activities to ensure reliable and safe operation of equipment and systems.
- The power plant management should develop communication and implementation of management's expectations.
- The power plant should develop the implementation of human performance tools to control human errors. (International Atomic Energy Agency, 2018.)

Loviisa NPP management stated that it would address the improvement areas and request a follow-up from IAEA's Operational Safety Review Team approximately in 18 months (International Atomic Energy Agency, 2018). Hence, a follow-up evaluation was conducted to Loviisa NPP in year 2020 (International Atomic Energy Agency, 2020).

The evaluation team stated that Loviisa NPP has developed operational safety in many areas, such as emergency preparedness and severe accident management since the previous evaluation. The team leader said that the team is pleased to observe development in the areas identified in 2018. Following recommendations from year 2018 evaluation has been fully addressed:

- Loviisa NPP has strengthened updates and regular reviews of the severe accident management function.
- The power plant has developed the usage of human performance tools to prevent work errors.

- The power plant has developed its emergency preparedness and increased practical training for employees in emergency preparedness. (International Atomic Energy Agency, 2020.)

Although significant process has been made in increasing operational safety in Loviisa NPP, there were still some development areas of year 2018 recommendations such as:

- continuing to improve the storage and control of maintenance tools and lifting equipment,
- further development in implementation of management's expectations,
- continue the development of maintenance work practices (Operational Safety Review Team, 2020).

5 IDENTIFIED GAPS AND POSSIBLE IMPROVEMENTS IN LOVIISA NPP

5.1 Comparing Loviisa NPP to High Reliability Organisation model

This chapter concludes the gaps identified in the former evaluations and compares them to theoretical and empirical studies sited in this thesis. More particularly, the comparison focuses on the HRO characteristics presented in chapter 3.5. The HRO model was chosen for comparison since the model is specifically targeted for industry areas in which potential for large-scale accidents exist. Table 5 summarises the different HRO factors hierarchically.

Table 5. Summary of HRO characteristics

Core HRO characteristic	**Related HRO characteristics**
Clarity of objectives (Saunders, 2015)	• Accountability flows from top to bottom (Gentzel, et al., 2019). • Clearly defined roles and responsibilities (Gentzel, et al., 2019). • HROs communicate the big picture of the organisation's goals. (Roberts & Bea, 2001) • HROs use focus groups, employee surveys and interviews to ensure that the real goals of the organisation are the same as the publicly stated goals (Roberts & Bea, 2001).
Strong organisational culture (Saunders, 2015)	• Concentrating on constructing a culture, where it is normal and frequent for employees to respectfully interact (Sutcliffe, 2011). • Employees are authorized to fix problems (Roberts & Bea, 2001). • Employees are conscious of organisational commitment to prevent accidents. (Roberts & Bea, 2001).
Presence of redundancy and slack (Saunders, 2015)	• Evolving resilience to manage unexpected events (Sutcliffe, 2011).
Mindfulness (Saunders, 2015)	• HROs seek to know and understand things that they do not yet know (Roberts & Bea, 2001). • Employees are open minded in their thinking regarding to accidents and solutions (Roberts & Bea, 2001). • Promoting an environment where employees interrelate mindfully (Sutcliffe, 2011). • HROs initiate set of procedures that makes possible to track minor failures (Sutcliffe, 2011). • Avoid oversimplification of work events (Sutcliffe, 2011). • Remain sensitive to current operations (Sutcliffe, 2011).
Ability to prosper in the paradoxes (Saunders, 2015)	• Maintain capabilities for resilience (Sutcliffe, 2011). • Employees are aware of the possibility of accident (Roberts & Bea, 2001). • Employees are able to conduct appropriate responses, avoid decoys and develop dissociating strategies (Roberts & Bea, 2001).
Deep knowledge of technical characteristics (Leveson, et al., 2009)	• Equipment-reliability procedures (Gentzel, et al., 2019). • Recognize parts of the systems that need to have redundancies (Roberts & Bea, 2001).
Stable technical processes and operation experience (Leveson, et al., 2009)	• Strict processes (Gentzel, et al., 2019). • Root-cause problem solving (Gentzel, et al., 2019). • Evolve a science of accidents that can happen in that specific organisation (Roberts & Bea, 2001). • HROs create Incident Command Systems as a standing procedure with strict and well-known decision rules about when they are put in motion. (Roberts & Bea, 2001)

5.1.1 Clarity of objectives

Respective characteristic comprehends that management sets and communicates unambiguously clear reliability standards. The standards are included in reliability indicators and they are visualised and distributed to the whole organisation. Further, the outcomes are discussed at all organisation levels. (Gentzel, et al., 2019.) HROs also communicate the big picture of the organisation's goals (Roberts & Bea, 2001).

HRO characteristic regarding to management expectations was identified as an improvement opportunity in this study. OSART mission in 2018 made a recommendation for improving communication and implementation of management's expectations (International Atomic Energy Agency, 2018). In year 2019, there were identified potential improvement areas in leadership accountability (World Association of Nuclear Operators, 2019). Whereas, in year 2020, there was identified possibility for further development of management expectations implementation (Operational Safety Review Team, 2020). Regarding to the latest evaluation, the management expectations have been clarified and the improvement opportunity lies in the implementation of these expectations.

The former improvement opportunity might also have an impact on the consistency of formal and informal organisation. When the formal and informal organisations are consistent and in sync, the organisational goals and values are strengthened in the organisation (Gulati & Puranam, 2009). However, when the messages from the formal and informal organisation are not the same, it makes it harder to work towards common goals and values. The message from formal organisation is related to the management's expectations, and if there is a room for improvement in the implementation of management's expectations, there is a possibility for harmful inconsistency of formal and informal organisation. In other words, the informal organisation might spread messages or procedures which are in conflict with management's expectations. However, the evaluations conducted for Loviisa NPP did not identify the latter phenomenon.

HRO characteristic regarding to clearly defined roles and responsibilities is satisfied regarding to the evaluations. As work group (2019) states: roles and responsibilities in the organisation were clearly described, defined and understood.

5.1.2 **Strong organisational culture**

One HRO characteristic related to strong organisational culture means respectful interaction, which is a key enabler in HRO. If respectful interaction is absent, employees might not communicate their observations and analysis to other employees. There are three norms for respectful interaction which include trust, honest interaction and self-respect. (Sutcliffe, 2011.)

Regarding to safety culture questionnaire, the statement "environment of trust prevails in the whole organisation has a score of 3,66 in a scale from one to five and the statement "relationships between management and personnel are based on trust" has a score of 3,85 (Päivärinta, 2019). These scores are at good level and the trend is positive. Work group (2019) also observed that an environment of trust is present in the organisation.

Honest interaction is also observed to prevail in Loviisa NPP. Safety culture questionnaire in 2018 resulted a score of 3,57 with a positive trend in terms of supervisors trying to increase openness and communication in the whole organisation (Päivärinta, 2019). Moreover, it is also observed that respectful work environment and environment for raising concerns were evaluated as strong characteristics in Loviisa NPP (World Association of Nuclear Operators, 2019). There were no indicators particularly on the current situation of self-respect but overall performance on respectful interaction is at a good level and there are no gaps identified in this HRO characteristic.

There were no clear indications of characteristic "employees are authorized to fix problems" in the evaluations, however a positive factor to this is that environment of trust is present in Loviisa NPP. Regarding to characteristic "employees are conscious of organisational commitment to prevent accidents" is evident in safety culture questionnaire where "safety is a clearly recognized value" had the score of 4,06 which has improved from previous questionnaire's result (Päivärinta, 2019).

5.1.3 **Presence of redundancy and slack**

The evaluations did not clearly indicate any strengths or improvement potential on the presence of redundancy and slack, but regarding to related HRO characteristic "resilience

to manage unexpected events", the Loviisa NPP has clear instructions for these type of events.

Loviisa NPP's operative decision making instruction states that decision making needs to follow conservative decision making culture and take into account safety aspects. Risks and benefits must be identified and assessed. Furthermore, decisions also need to be documented and distributed to the organisation. The line-up for the operative decision making meeting is constructed by responsible employees of the related area. Also, related system's responsible personnel, project managers and outage planners need to be invited to the meeting. Initiating the meeting can be done by anyone in the organization and unit managers usually summon the meeting. The chairman is decided by the event and matter in hand. In major events, the priority is to have the responsible on duty manager as the chairman. It is also noted that in decision making, all parties are heard and everybody should participate actively. (Eurasto, 2018.)

5.1.4 **Mindfulness**

Regarding to seeking to know and understand things that the organisation do not yet know, the World Association of Nuclear Operators (2019) identified potential improvement areas in risk and problem identification. The evaluations did not have evidence for or against to "open minded thinking regarding to accidents and solutions". In addition, mindful interrelating was not observed in the evaluations.

Regarding to practices to track minor failures includes pre and post job briefings in Loviisa NPP. It has been noted that the realisation of pre and post job briefings needs to be followed and confirmed (Work group, 2019). It is also stated that pre and post job briefings must be executed by following the instructions and increasing the information usage of operational experience events in these meetings (CAP-group, 2019).

Furthermore, World Association of Nuclear Operators (2019) identified a potential improvement area in threshold for deficiencies identification. Nevertheless, there has been improvement in this area in recent years as the frequency of observations and safety walks has increased as described in Figure 19.

Figure 19. Observation reports and safety walks in Loviisa NPP.

Increasing amount of observation reports indicates the improvement in the low threshold for identification of deficiencies, identifying minor deficiencies and open organisational culture.

HRO characteristic related to mindfulness "avoiding oversimplification of work events" includes the open environment for questioning actions and bringing out alternative opinions (Vogus & Sutcliffe, 2007). Loviisa NPP has an identified strength in environment for raising concerns, whereas questioning attitude, in turn, was identified as a potential improvement area (World Association of Nuclear Operators, 2019).

HRO characteristic "sensitivity to operations" includes information sharing and interaction about current organisational and human factors. Indeed, it should be seen as frequent interaction between employees to build a common understanding of what is currently happening. In addition, employees should also have a good chart of organisation's different talents and skills. (Vogus & Sutcliffe, 2007.)

In Loviisa NPP, the information sharing is considered to be at a good level as Loviisa NPP has open work environment and transparent decision making (CAP-group, 2019). There are no clear indications in the evaluations in terms of interaction about current organisational and human factors in the conducted evaluations. Relating to chart of

organisation's talents and skills, there is an ongoing development project on knowledge management where the goal is to have procedures and a tool for knowledge management (Solja, 2019).

5.1.5 Ability to prosper in the paradoxes

The HRO characteristic "maintaining capabilities for resilience" in Loviisa NPP is coordinated by operation experience function. Operation events are processed by operation experience group in cooperation with the target function. Goals of the operation experience learning are to communicate the occurred events, prevent future events with corrective actions and to learn from the events.

5.1.6 Deep knowledge of technical characteristics

From technical point of view Loviisa Nuclear Power Plant has many strengths regarding to HRO characteristics. One such HRO characteristic is that HROs has nearly perfect knowledge of the technical characteristics of operations (Leveson, et al., 2009). For example, in the OSART mission in 2018, it was identified that Loviisa NPP has established a process simulation software to test and improve plant engineering process during design of modifications and upgrades (Operational Safety Review Team, 2020).

Moreover, HROs have also clearly defined assets that are crucial to their operations and equipment reliability procedures and they are followed by closely monitoring equipment health. (Gentzel, et al., 2019). Loviisa NPP has safety significance-based categorisation for all systems, structures and components that were scoped and screened into Ageing management program that had been established and utilised at the power plant (Operational Safety Review Team, 2020).

5.1.7 Stable technical processes and operation experience

HRO characteristic regarding to strict reliability processes has some potential improvement areas in Loviisa Nuclear Power Plant. It is observed that instructions are sometimes hard to find due to large amount of instructions and there has been some cases where instructions were in conflict with each other. This may lead to a case in which

following one instruction may violate another. Also, some cases have been observed where instructions have not been followed or instructions are out of date. (CAP-group, 2019.)

The power plant's managers and work supervisors have brought up that personnel is more involved in the process of updating instructions than before. Indeed, personnel also stated that effort has been made for the better involvement of personnel. On the other hand, it was brought up that updated versions of instructions or work plans are not sent early enough for comments to the personnel who knows the work in practise. (Work group, 2019.)

On the other hand, work group (2019) observed that instructions are known and followed, thus the observations by CAP-group (2019) about cases in which instructions are not followed are presumably very rare. In addition, safety and following related instructions were central and natural part of the operations for the personnel. Nonetheless, the evaluation also identified potential improvement areas in quality, usability and findability of instructions and work order quality and accuracy should be in higher attention (Work group, 2019).

Regarding to safety culture questionnaire, the statement "The quality of documents and instructions are on high level" had the score of 3,77 which is considered good. Another statement "The quality of processes from planning to executing is on high level" had the score of 3,59. Both statements had positive trend from the year 2016 questionnaire. (Päivärinta, 2019.)

Regarding to stable technical processes the Loviisa NPP has almost completed the development of the main processes (CAP-group, 2019). Regarding to operation experience the work group (2019) states that operation experience function and assessment of effectiveness has developed further in the recent years, however several personnel changes are setting challenges. It is also stated that the plant management needs to provide strong support for operation experience function and provide appropriate resources for it (Work group, 2019). Reporting and trending of operation experience has improved with a dedicated tool for observation trending and there has been established a

specific training to all personnel regarding identifying and reporting low level issues (Operational Safety Review Team, 2020).

5.2 Improvement areas and possible corrective actions for Loviisa NPP

In terms of potential improvement area in management's expectations implementation and the possible conflict with informal organisation's goals, Loviisa NPP could use focus groups, employee surveys and interviews as described by Roberts & Bea (2001) to ensure that the goals of the informal organisation are in line with the formal management's expectations and thus make sure that the expectations are being implemented to the field successfully.

HRO characteristic "set of practices are initiated that makes possible to track minor failures and avoid oversimplification of work events" has potential improvement opportunity in the implementation of pre and post job briefings. Also, using operation experience events in the pre and post job briefings has a potential improvement possibility. Line managers should encourage and highlight the importance of the pre and post job briefings to the personnel and lead by giving example.

Furthermore, threshold for identifying and reporting deficiencies could be further improved. One of the Big Rocks is "Field observations and actions" thus there are no shortcomings in setting management's expectations in this area, however better implementation would be needed in order to ensure organisation's capability to track minor failures proactively.

Regarding to potential improvement area in questioning attitude the Loviisa NPP's Big Rocks or nuclear professional guide does not have clear statements about questioning attitude. Although there is a relating statement in the nuclear professional guide in Figure 16 "I communicate and listen to others and bring up my own views.", this area could be indicated more clearly in the Loviisa NPP management's expectations. It could also be beneficial to implement expectations towards curiosity value as a whole.

The area of strict reliability processes had improvement potential in the quality of instructions and the respect towards instructions. One possible root cause for not following instructions could the lack of involvement of the personnel with deeper knowledge and who actually does the work in the field. Other possible root cause could be within the instruction process in which usability and findability has improvement opportunities.

In one of the year 2020 CAP-group meetings, there was raised possible improvement potential of the current process for reporting and correcting inconsistencies in instructions. These improvement opportunities could be brought up into higher attention and thus solved throughout the organisation to improve the current state regarding to strict reliability processes characteristic.

Currently, the Loviisa NPP's Big Rocks include "ensuring excellent work practices" but there is no direct mention of the importance of the instructions. There could be addition such as "instructions are strictly followed and if inconsistencies are identified they are reported". Even if this type of statement would be added in the management expectations, the gap of the implementation of management expectations should be also solved.

Learning from operational experience has improved in Loviisa NPP, but there still remains to be identified improvement opportunities in this area in the recent evaluations. Further, more comprehensive operation experience learning requires improvement from the operation experience investigation methods and the support to it. The support should include more support from management as well as greater ownership and initiative from line managers (Work group, 2019). Moreover, this improvement opportunity links to the area of management's expectations. Line managers should implement strong support for participating and taking ownership of operation experience investigations.

Ideally, the main responsibility for operation experience investigation should be in the function where the event has happened and where the deep knowledge of the event resides. The operation experience function could be the supporting function which provides the suitable research methods and an independent and different point of view to the event investigation. The success of this method would require high level of openness,

self-criticism and respectful interaction from the responsible function. This would also require strong encouragement and example setting from management.

6 CONCLUSION

There were no identified major gaps in the HRO characteristic, but possible improvement areas were identified in Loviisa NPP. The main research question was “what are the gaps and possible improvements of Loviisa Nuclear Power Plant’s performance?” and the sub research questions were:

- What are the identified gaps in Loviisa NPP?
- What are the identified strengths in Loviisa NPP?
- What improvements could be done in Loviisa NPP?

Identified gaps compared to HRO characteristics in Loviisa NPP were:

- implementation of management’s expectations,
- high threshold for risk and problem identification,
- practices to track minor failures,
- questioning attitude,
- quality, findability and usability of instructions,
- quality and accuracy of work orders,
- operation experience learning.

Identified strengths compared to HRO characteristics in Loviisa NPP were:

- environment of trust,
- respectful interaction,
- environment for raising concerns,
- process simulation software,
- safety significance-based categorization.

Possible corrective actions in Loviisa NPP could be:

- using focus groups, employee surveys and interviews to ensure the sync of formal and informal goals,
- more attention to instructions and throughout analysis of current instruction system to find root causes,
- improving operation experience investigation methods and more support from the Loviisa NPP management to the operation experience function,
- better implementation of management’s expectations about pre and post job briefings,

- better implementation of management's expectations about identifying and reporting deficiencies.

The main gaps comparing to HRO characteristics were in implementation of management expectations and in strict reliability processes. According to Gentzel et al. (2019), in Figure 14, these two areas are included in the main three enablers for HROs.

Loviisa NPP's two major strengths regarding to HRO characteristics were in technical knowledge of operations and respectful interaction. Further, there were indications of trust and honest interaction in Loviisa NPP which are the key enablers for HROs. It could be beneficial to take full advantage of these organisational culture strengths in the process of improving the main gaps identified.

It can be noted that these research questions were answered but a deeper analysis of strengths and gaps could be made. There were also some characteristics that were not processed in the evaluations like:

- employees are authorized to fix problems (Roberts & Bea, 2001),
- presence of redundancy and slack (Saunders, 2015),
- evolving resilience to manage unexpected events (Sutcliffe, 2011).

It would be also beneficial to dig deeper into the causes of the main two identified gaps and how to solve them thoroughly. It is also possible that if these two major gaps are solved it would have positive effect on other areas of improvement possibilities.

All in all, Loviisa NPP has a healthy organisational culture and proper infrastructure to improve performance as continuous improvement. In addition, Loviisa NPP's performance improvement has a positive trend as stated by IAEA OSART: "Fortum, the operator of the Loviisa nuclear power plant in Finland, has strengthened operational safety in many areas, an expert team from the International Atomic Energy Agency (IAEA) has concluded." (World Nuclear News, 2020.)

7 BIBLIOGRAPHY

Anand, N. & Daft, R. L. 2007. What is the Right Organization Design?. In: *Organizational Dynamics.* Toronto: ScienceDirect, pp. 329-344.

Bazigos, M. & Harter, J. 2016. *Revisiting the matrix organization.* [Online] Available at: https://www.mckinsey.com/business-functions/organization/our-insights/revisiting-the-matrix-organization. [Accessed 25th February 2020].

CAP-group. 2018. *CAP-ryhmän vuosiraportti 2017.* Loviisa: Fortum Power and Heat Oy. Internal document.

CAP-group. 2019. *CAP-ryhmän vuosiraportti 2018.* Loviisa: Fortum Power and Heat Oy. Internal document.

Costa, L. A. & Matos, J. 2013. *Attitude change in arbitrarily large organizations.* New York: Springer Science+Business Media.

Daft, R. L., Murphy, J. & Willmott, H. 2010. *Organization Theory and Design.* Thomas Rennie.

Eurasto, T. 2018. *Operatiivinen päätöksenteko Loviisan voimalaitoksella.* Loviisa: Fortum Power and Heat Oy. Internal document.

Eurasto, T. 2019. *Käyttöyksikön organisaatio ja tehtäväalueet.* Loviisa: Fortum Power and Heat Oy. Internal document.

Eurasto, T., Järvinen, M.-L., Sandberg, J. & Sjöblom, K.-L. 2004. Ydinvoimalaitostekniikan perusteita. In: *Ydintruvallisuus.* Hämeenlinna: Säteilyturvakeskus, p. 45.

Fortum Oyj. 2019. *Governing bodies.* [Online] Available at: https://www.fortum.com/about-us/investors/corporate-governance/governing-bodies. [Accessed 5th February 2020].

Fortum Oyj. 2019. *Intranet Fortum Internal site.* [Online] Available at: https://fortum.sharepoint.com/sites/company-en. [Accessed 5th February 2020].

Fortum Oyj. 2019. *Loviisa nuclear power plant.* [Online] Available at: https://www.fortum.com/about-us/our-company/our-energy-production/our-power-plants/loviisa-nuclear-power-plant. [Accessed 8th February 2020].

Fortum Oyj. 2019. *Shareholders' Nomination Board.* [Online] Available at: https://www.fortum.com/about-us/investors/corporate-governance/shareholders-nomination-board. [Accessed 8th February 2020].

Fortum Oyj. 2019. *Tietoa meistä.* [Online] Available at: https://www.fortum.fi/tietoa-meista. [Accessed 8th February 2020].

Fortum Power and Heat Oy. 2017. *Fortumin ydinvoimatoimintojen turvallisuus- ja laatupolitiikka.* Loviisa: Fortum Power and Heat. Internal document.

Fortum Power and Heat Oy. 2019. *Loviisa teemat 2019 one pager,* Loviisa: Fortum power and Heat Oy. Internal document..

Fortum Power and Heat Oy. 2019. *Ydinvoima-alan ammattilainen Loviisan voimalaitoksella Nuclear Professional at Loviisa NPP.* Loviisa: Internal document.

Fortum. 2019. *Reporting structure.* [Online] Available at: https://www.fortum.com/about-us/investors/key-facts/reporting-structure. [Accessed 8th February 2020].

Gable, G. G., Hu, H. & Chen, L. 2012. *Communication and organizational social networks a simulation model.* Springer Science+Business Media.

Gentzel, M., Hessney, E., McDonnell, B. & Thibert, J. 2019. *What high-reliability organizations get right.* [Online]

Available at: https://www.mckinsey.com/business-functions/operations/our-insights/what-high-reliability-organizations-get-right. [Accessed 25th February 2020].

Gray, J. L. & Starke, F. A. 1984. *Organizational Behaviour: Concepts and Applications.* Columbus: Chrales E. Merrill.

Gulati, R. & Puranam, P. 2009. *Renewal Through Reorganization: The Value of Inconsistencies Between Formal and Informal Organization.* INFORMS.

Heikkilä, A. 2019. *Toimintaprosessien johtaminen,* Loviisa: Fortum Power and Heat Oy. Internal document.

Hernaus, T. 2008. *Process-Based Organization Design Model: Theoretical Review and Model.* Zagreb: SSRN Electronic Journal.

Huczynski, A. & Buchanan, D. 2001. *Organizational Behaviour.* Harlow: Pearson Education Limited.

Inkala, A. 2017. *Kunnossapito.* Loviisa: Fortum Power and Heat Oy. Internal document.

International Atomic Energy Agency. 2009. *The management system for nuclear installations.* Vienna: International Atomic Energy Agency.

International Atomic Energy Agency. 2018. *IAEA Says Finland's Loviisa Nuclear Power Plant Committed to Safety, Sees Areas for Enhancement.* [Online] Available at: https://www.iaea.org/newscenter/pressreleases/iaea-says-finlands-loviisa-nuclear-power-plant-committed-to-safety-sees-areas-for-enhancement [Accessed 12 March 2020].

International Atomic Energy Agency. 2020. *IAEA Safety Mission Sees Significant Progress at Finland's Loviisa Nuclear Power Plant, Encourages Continued Improvement.* [Online] Available at: https://www.iaea.org/newscenter/pressreleases/iaea-safety-mission-

sees-significant-progress-at-finlands-loviisa-nuclear-power-plant-encourages-continued-improvement [Accessed 12 March 2020].

Joyce, W. F. 1986. *Matrix Organization: A Social Experiment.* Hanover: Academy of Management Journal.

Katajala, S., Leinonen, R. & Blomqvist, R. 2019. *Loviisan voimalaitoksen johtosääntö.* Loviisa: Fortum Power and Heat Oy. Internal document.

Laakso, A. 2019. *Kunnossapitotekniikan organisaatio ja tehtäväalueet.* Loviisa: Fortum Power and Heat Oy. Internal document.

Leinonen, R. 2017. *Fortumin ydinvoimatoimintojen turvallisuuskulttuuriohjelma.* Loviisa: Fortum Power and Heat Oy. Internal document.

Leveson, N., Dulac, N., Marais, K. & Carroll, J. 2009. *Moving Beyond Normal Accident and High Reliability Organizations: A Systems Approach to Safety in Complex Systems.* Massachusetts: SAGE Publications.

Loviisa NPP's management team. 2018. *Loviisan voimalaitoksen pitkän aikavälin strategia.* Loviisa: Fortum Power and Heat Oy. Internal document.

Mäkinen, P. 2019. *Fortumin luvanvaraisen ydinvoimatoiminnan johtamisjärjestelmä.* Loviisa: Fortum Power and Heat Oy. Internal document.

Nuclear Energy Act. 1987. *Ydinenergialaki 11.12.1987/990.* [Online] Available at: https://www.finlex.fi/fi/laki/ajantasa/1987/19870990. [Accessed 4th March 2020].

Oedewald, P. 2018. *Käytön tarkastusohjelman vuoden 2018 tarkastus: Fortum: johtaminen ja turvallisuuskulttuuri.* Helsinki: Säteilyturvakeskus.

Oedewald, P. & Gotcheva, N. 2015. *Safety culture and subcontractor network governance in a complex safety critical project.* Reliability Engineering and System Safety.

Päivärinta, J. 2019. *Liiketoimintayksikön organisaatio.* Loviisa: Fortum Power and heat Oy. Internal document.

Päivärinta, J. 2019. *Safety Culture Survey 2018 - results,* Loviisa: Fortum Power and Heat Oy. Internal document.

Reijers, H. A. 2006. *Implementing BPM systems: the role of process orientation.* Eindhoven: Emerald Group Publishing Limited.

Roberts, K. H. & Bea, R. 2001. *Must accidents happen? Lessons from high-reliability organizations.* ABI/INFORM Collection.

Ropponen, A. 2017. *Loviisan voimalaitoksen CAP-ryhmän työjärjestys.* Loviisa: Fortum Power and Heat Oy. Internal document.

Ropponen, A. & Kivirinta, T. 2017. *CAP-ryhmän vuosiraportti 2016.* Loviisa: Fortum Power and Heat Oy. Internal document.

Saunders, F. C. 2015. *Toward high reliability project organizing in safety-critical projects*: Project Management Journal.

Saunders, F. C., Gale, A. W. & Sherry, A. H. 2016. *Responding to project uncertainty: Evidence for high reliability practices in large-scale safety-critical projects.* Manchester: Elsevier Ltd..

Selznick. 1948. *Foundations of the theory of organization.* American Sociological Review.

Solja, T. 2019. *Osaamisenhallinta Loviisan voimalaitoksella,* Loviisa: Fortum Power and Heat Oy. Internal document.

STUK. 2019. *Leadership and management for safety, 15.3.2019.* [Online] Available at: https://www.stuklex.fi/en/ohje/YVLA-3. [Accessed 8th February 2020].

Sutcliffe, K. M. 2011. *High reliability organizations (HROs).* Michigan: Elsevier Ltd.

Säteilylaki. 2018, 859/2018. [Online] Available at: https://www.finlex.fi/fi/laki/alkup/2018/20180859. [Accessed 4th March 2020].

Tuunanen, J. 2018. *Ydinpolttoaine- ja jätehuolto -yksikön organisaatio.* Loviisa: Fortum Power and Heat Oy. Internal document.

University of Minnesota Libraries Publishing. 2017. *Organizational Behavior*. Minnesota: University of Minnesota Libraries Publishing.

Vanhanen, J. 2019. *Ydinturvallisuusyksikön organisaatio.* Loviisa: Fortum Power and Heat Oy. Internal document.

Vanhaverbeke, W. & Torremans, H. 1999. *Organizational Structure in Process-based Organizations.* John Wiley & Sons Ltd and Cornwallis Emmanuel Ltd.

Weick, K. & Roberts, K. 1993. *Collective mind in organizations: heedful interrelating on flight decks.* Adminstrative Science Quarterly.

Weick, K., Sutcliffe, K. & Obstfeld, D. 1999. *Organizing for high reliability: processes of collective mindfulness. In Staw BM & Cummings LL (eds.).* Greenwich: JAI Press.

Vogus, T. & Sutcliffe. 2007. *The impact of safety organizing, trusted leadership, and care pathways on reported medication errors in hospital nursing units.* Medical Care.

Vogus, T. & Sutcliffe, K. 2007. *The safety organizing scale: development and validation of a behavioral measure of safety culture in hospital nursing units.* Medical Care.

Work group. 2019. *A45: Selvitys luvanhaltijan turvallisuuskulttuurista ja -johtamisesta - selvitys turvallisuuskulttuurista.* Loviisa: Fortum Power and Heat Oy. Internal document.

World Association of Nuclear Operators. 2019. *WANO MC Peer Review Final Report.* Fortum Power and Heat Oy. Confidential document.

World Nuclear News. 2020. *IAEA finds improved operating safety at Loviisa.* [Online] Available at: https://world-nuclear-news.org/Articles/IAEA-finds-improved-operating-safety-at-Loviisa. [Accessed 25th March 2020].

Ydinvastuulaki. *1972, 8.6.1972/484.* [Online] Available at: https://www.finlex.fi/fi/laki/ajantasa/1972/19720484. [Accessed 4th March 2020].