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Learning from Successes in Nuclear Power Plant Operation - Intermediate Report from the NKS-R LESUN

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Abstract

Learning from experience is essential to achieve safe and efficient operations at nuclear power plants. In the nuclear industry, licensees are required to collect lessons from unwanted events in order to prevent the recurrence of similar events. This implies focus on learning from failures, which may limit the opportunities of the organisation to develop. Modern safety theories such as Resilience Engineering suggest that also using successes as sources for learning may be beneficial.

In this project we elaborate the concept of success in nuclear industry and how it can be utilized for learning purposes. The scope of this intermediate report is to provide insights to how successful actions and decisions can be captured and how learning processes from successes and failures differ from each other. To achieve this we carried out an extensive literature review and two case studies in nuclear power plants.

We found that success is a complex and multidimensional concept that can take many forms. We identified three broad categories of success: normal performances, extraordinary performances and recoveries. We also observed that success can have properties such as time and situation-dependence and that it relates to the objective or subjective expectations of multiple stakeholders. Based on our findings we formulated a preliminary framework for capturing successes. We propose that this framework can be useful to identify successful situations for learning purposes.

We also found that successes are often less salient and less likely to trigger intentional learning processes than failures. Regardless, we found in our empirical studies that there was clear interest in successes at the power plants: existing methods, albeit not very refined, were already in place that could be utilized to learn from successes more systematically. Further developing these activities is also important in order to avoid unwanted side-products of learning from success such as organisational drift or complacency. In addition, because lessons learned from success are often tacit, exploring the possibilities of developing learning that relates to tacit knowledge may be useful. Operating experience activities have a central role in facilitating the development of these learning activities.

Key words

Success, adaptive performance, operating experience, organisational learning, safety, resilience engineering

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(Contract: NKS_R_2015_115)

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1 Introduction

Organisational learning is widely seen as an important constituent for ensuring and sustaining the competence, performance and success of organisations (see e.g. Argote & Miron-Spektor, 2011; Kim, 1998; Senge, 1990). In safety-critical contexts, such as the nuclear industry, achieving and maintaining acceptable level of safety and reliability of operations is an imperative. The underlying reasoning why learning is such an essential aspect to safety-critical organisations is because it is assumed to enable the organisation to respond effectively to environmental challenges and turbulence, and to avoid the occurrence of adverse events (IAEA, 2002). It is therefore not surprising that in safety-critical contexts there has traditionally been great interest in developing various learning processes within and between organisations. In the nuclear industry many learning processes are highly advanced and institutionalised. This is reflected both in the content of guidelines and recommendations of various umbrella organisations that, for example, expect nuclear organisations to continuously learn (WANO, 2013), embrace organisational learning (INPO, 2004) or engage in learning-driven safety development (IAEA, 2008b) and in the requirements of many national and international regulatory bodies that enforce the implementation of practices such as operating experience (e.g. IAEA, 2009; STUK, 2014b).

Nuclear operating experience activities primarily consist of collecting different types of data about the activities at the plant, analysing them and providing corrective action plans and lessons learned to own organisation and peer organisations. This includes analysing and reporting of incidents and breaches of Operational Limits and Conditions, but also minor events which have had no direct effect on plant safety (Pietikäinen et al., 2010). In addition to analysing and reporting adverse events, utilizing techniques such as collecting improvement suggestions or good working practices are also encouraged (IAEA, 2008a, 2010). However, in practice operating experience activities are rather focused on adverse events and prevention of their reoccurrence (Pietikäinen et al., 2010).

Some modern developments in safety science, such as the Resilience Engineering tradition, have questioned the efficiency of traditional approaches to learning and safety development and have presented alternative viewpoints. Hollnagel (2013) refers to the traditional approach, which emphasizes avoiding things that “go wrong”, as “Safety-I”. Safety-I approach focuses on identifying the causal links that have led to a failure and then attempts to eliminate them (Hollnagel, 2013). This process often involves utilizing elaborate event investigations to pinpoint the failures and then suggesting classic “human error” reduction techniques such as adding of more barriers, proceduralizing work or creating checklists as a corrective action (Dekker, 2002). In simple systems and those at early stages of development, Safety-I approaches to safety management are more likely to be beneficial because they are able to catch the most obvious and urgent issues, however, once the system becomes increasingly complex and failures rarely take place, Safety-I approaches begin to show symptoms of their limitations. Safety-I approaches are essentially based on the assumption that systems are stable, perfectly designed and predictable (Dekker, Cilliers, & Hofmeyr, 2011; Hollnagel, 2013). Furthermore, Safety-I assumes that one could resolve any performance problem by removing confounding agents or conditions and make meaningful predictions from failed events.

Relying on a Safety-I approach also implies that once an organisation reaches a state in which everything goes as planned and adverse situations are very rare, the learning and development of the organisation might be hindered. Hollnagel (2013) refers to generic approximations of accident frequencies in different types of organisations (Amalberti, 2006) and argues that the opportunities for learning in particularly safe systems are likely to be severely hindered by the Safety-I approach – in ultra-safe systems such as nuclear power plants, this frequency may be as low as one accident per million events or lower (Amalberti, 2001, 2006). Such a situation may even contribute to a decrease of safety because the system has little opportunities for further development of safety: if the organisation is reactive and very preoccupied with failures as their main (or even only) source of information and knowledge, this source will be paradoxically drained as the organisation becomes safer and more reliable.

To some extent massive and complex socio-technical systems such as nuclear power plants may appear to behave in such a manner that is compatible with Safety-I safety management approaches – such systems may sometimes also produce simple events that can be scrutinized using Safety-I approaches and this may provide useful lessons or information for corrective actions. In addition, proper analysis of significant adverse events is typically enforced by regulators and it also reflects good safety management practices – however, ultimately the potential for extracting lessons using only these means is limited. Complementary to the Safety-I approach, it is argued that in order to sustain safety effectively, the organisation also needs to ensure that things "go right" (Hollnagel, 2013). This approach to safety management is coined "Safety-II".

Safety-II emphasizes the idea that an organisation should focus on understanding the reasons behind successful activities; in essence this refers to the successful everyday work that is largely ignored by Safety-I approaches (Hollnagel, 2013). Safety-II assumes that systems are in a state of imperfection and constant change – as opposed to Safety-I – and suggests that it is the ability to cope under various conditions that ensures system's safety and reliable performance (Hollnagel, 2013). The key concept here is performance variability, which refers to the ability to constantly adapt and adjust to the surrounding environment and its requirements. This performance variability is seen both as a source of successes and failures – the adaptation that has failed leads to failed outcome, and adaptation that has succeeded leads to a successful outcome. Safety-II approaches hold that this performance variability shouldn't be completely removed like many human error reduction programs attempt to do, because this would result in humans behaving in a machine-like manner: effectively losing their ability to contribute to the sustained safe activities of the safety-critical organisation. The fundamental message of Safety-II therefore is that human performance variability needs to be maintained in such a manner that it leads to positive outcomes: successful performance adaptations. Identifying the contributing factors that affect successful performance adaptations may provide a rich source of information regarding how a safety-critical organisation ensures its performance both in expected and unexpected conditions.

Recognizing the likely void of Safety-II approaches in the nuclear industry and the general lack of practical guidelines, toolsets or other means for learning from things that "go right", the overall objective of the project LESUN is to contribute to improving nuclear safety by developing principles that aim to enhance learning from successful activities. We will be especially focused on operating experience activities, because they can be seen as one of the main deliberate means of managing organisational learning in nuclear industry. LESUN principles are planned to include capturing, analysing and communicating lessons learned from successful actions and decisions. The main focus of the principles will be on performance adaptations of shop-floor staff. We expect these principles to augment established operating experience work by bringing out relevant information that was previously either unavailable or ignored due to the largely failure-oriented practices.

The development of the principles is an iterative process – in this report we present the preliminary version, which is planned to be further refined next year. LESUN principles will be based on theoretical work that involves literature review and synthesis of researchers' existing knowledge, empirical studies at nuclear power plants and collaboration with operating experience personnel.

The following research questions guide the progress of LESUN:

1) How to learn from successes? What kinds of theoretical models and practical concepts can be found from non-nuclear application areas?
2) What are the criteria for identifying successful performance adaptations?
3) What specifications should a method designed to support learning from successful performance adaptations fulfil? I.e. how should the current operating experience practices, e.g. event investigations, be developed in order to facilitate learning from successful actions and decisions?
4) How should successful performance be communicated to promote transfer of lessons learned between plants/units?

The study is ongoing and is planned to continue in the year 2016. Therefore, in this intermediate report we will focus mainly on research questions 1 and 2. We conducted a theoretical review of the concepts of adaptive performance, success and learning (chapter 2). This theoretical work provided insight to the idea of learning from success and a basis for our empirical studies which consist of two case studies at nuclear power plants. Two separate research entities were involved in the empirical case studies. Both worked in coordination but with different approaches, methods and focus in the case studies. This allowed more diversity and helped to produce potentially complementary findings. Preliminary results of empirical work are reported in chapters 3 and 4. The analysis of the empirical data will continue in 2016 and the results from empirical studies will be then further elaborated. The insights from both case studies were combined into a preliminary version of a success capturing framework and joint discussion of the results. Chapter 5 describes a preliminary version of our framework for capturing successful adaptations in nuclear power plant operations. Lastly, chapter 6 summarizes this year's activities and highlights the most important results of the project along with suggestions for next year's plans.

Reading guide

In order to get a *quick overview* of the essential topics of this study, the authors recommend reading the following pages:

- Practical implications of the study
  - Pages 83– 89 (principles for capturing successful performance adaptation)
- Overall study results and future plans
  - Pages 90 – 94 (conclusions)
- Literature review
  - Pages 11 – 12 (adaptive performance)
  - Pages 25 – 26 (the multidimensional nature of success)
  - Page 33 (organizational learning)
  - Page 39 (learning from successes and failures)
- Empirical work
  - Pages 69 – 72 (Plant A)
  - Pages 81 – 82 (Plant B)

2 Theory: How to learn from successes in nuclear industry

In order to develop a method for learning from success, and in particular capturing successful adaptations, we find it important to first examine the central concepts behind learning from success in nuclear maintenance context. We carried out a literature review in domains of safety science, individual, organisational and work psychology, and management sciences. This chapter is intended to provide a theoretical understanding of the research questions 1 and 2 and it includes the following:

- Review of the concept of adaptive performance in order to help identifying adaptations (chapter 2.1)
- Synthesis of various approaches to success in order to explicitly define success chapter (chapter 2.2)
- Review of the concept of organizational learning (chapter 2.3)
- Insights to the characteristics of learning processes that relate to success (chapter 2.4)

2.1 Adaptive performance

Resilience Engineering tradition and Safety-II approaches to safety management emphasize the importance of performance adaptations in ensuring successful performance. Resilience Engineering tradition has proposed four "cornerstones" that are thought to be essential for a system to be able to adjust to its environment and sustain its functioning (Hollnagel, 2009). These cornerstones are the system's ability to anticipate, the ability to monitor, the ability to respond and the ability to learn (Hollnagel, 2009; see also Pariès, Hollnagel, Wreathall, & Woods, 2012). In order to provide a sound theoretical basis for the case studies and the proposed successful adaptation capturing principles, we review existing literature from various domains regarding what exactly are adaptations in task-oriented situations and how they could relate to nuclear operations.

2.1.1 Types of adaptive performance

To our knowledge there are no readily available, comprehensive frameworks of adaptive performance in nuclear power plant maintenance. Previous studies of performance adaptations in nuclear maintenance context haven't provided a practical framework for the identification of adaptive performance and have mainly focused on "procedure adaptations", that involve the identification of when a procedure isn't either applicable or sufficient to carry out a task successfully and then adapting behaviour so that it reflects actual situation at hand (Gotcheva et al., 2013; Oedewald, Macchi, Axelsson, & Eitrheim, 2012).

Adaptive performance has been extensively studied in the fields of military training, trading, service organisations and IT-companies, and multiple frameworks for adaptive performance have been proposed in each of the organisational contexts. Perhaps one of the most influential frameworks is the one proposed by Pulakos, Arad, Donovan and Plamondon (2000). In their study Pulakos et al. (2000) reviewed over 1.000 incidents in various job tasks in military context in which adaptive behaviour (i.e. modification of behaviour to meet the demands of the situation) was demonstrated in order to uncover global facets of adaptive behaviour. They identified the following global facets: handling emergencies or crisis situations, handling work stress, solving problems creatively, dealing with uncertain and unpredictable work situations, learning work tasks, technologies and procedures, demonstrating interpersonal adaptability, demonstrating cultural adaptability and demonstrating physically oriented adaptability (Pulakos et al., 2000). Further descriptions of each of the facets are presented in

Table 1. Most of the aspects of adaptive behaviour don't relate to organisational phenomena but rather emphasize individual or team level behaviour. Griffin et al. (2007) have studied work role adaptation and proposed that in addition to the individual and team level adaptive performance, organisational level aspects should also be considered. Therefore, "coping with organisational changes" as identified in Griffin's et al. (2007) framework is added to Table 1.

Furthermore, a distinction has been made between proactive and reactive aspects of adaptive performance (e.g. Crant, 2000; B. Griffin & Hesketh, 2003; M. A. Griffin, Neal, & Parker, 2007). The reactive aspect of adaptive performance (i.e. changing or modifying oneself to better suit environment) can be related to the Resilience Engineering cornerstone of "responding to events", which is generally defined as the ability to handle regular or irregular disruptions (Pariès et al., 2012); respectively proactivity (i.e. initiating action) can be related to the Resilience Engineering cornerstone of "anticipating future threats". Proactivity in adaptive work performance literature is broadly defined as "*taking initiative in improving current circumstances [...] rather than passively adapting to present conditions*" (Crant, 2000). Crant (2000) reviewed a selection of studies in the field of proactivity to form an integrative model of proactive behaviour in the workplace. This model contains the concepts of proactive behaviour constructs and contextual factors as the antecedents to proactivity and provides examples of proactive behaviours that emerge as a consequence; finally, the proactive behaviours result in various outcomes such as better job performance (Crant, 2000). Crant (2000) identifies four general proactive behaviour constructs: proactive personality, personal initiative, role breach self-efficacy and taking charge (see descriptions in Table 1), which can be seen as applying to across a variety of situations. Furthermore, Crant (2000) describes a variety of context-specific proactive behaviours that have been discussed in literature: socialisation, feedback seeking, issue selling, innovation, career management and stress coping (see descriptions in Table 1). Even though Crant's review of proactivity studies doesn't discuss proactivity in safety-critical organisations, his work can be useful in describing the practical manifestations of proactive behaviour on a more general level in safety-critical organisations. Identifying such proactivity aspects as career management or issue selling might not necessarily be directly relevant to nuclear maintenance activities, but explicating relevant types of proactivity may help identifying performance adaptations in maintenance activities.

The "tolerant behaviour" facet of adaptive performance as suggested by B. Griffin and Hesketh (2003) doesn't appear to have a direct counterpart in Resilience Engineering tradition, but may however play an important role in the adaptive execution of a work task. This type of adaptive behaviour refers to the ability to continue functioning despite the changes in the environment or when proactive or reactive activities are not appropriate (B. Griffin & Hesketh, 2003). We applied the categorisation proposed by B. Griffin and Hesketh (2003) with modifications to identify the following tolerant behaviours from the adaptive performance frameworks of Pulakos et al. (2000) and Griffin et al. (2007): handling work stress, coping with uncertainty and unpredictable work situations, demonstrating interpersonal adaptability, demonstrating cultural adaptability, demonstrating physically oriented adaptability, coping with organisational changes. Tolerant adaptive behaviour can readily be related to nuclear maintenance activities that often require working in hot, humid or noise places (i.e. physically oriented adaptability), remaining calm under stressful or difficult situations (i.e. handling work stress) and collaboration with foreign 3rd parties (i.e. cultural adaptability).

The last Resilience Engineering cornerstone discussed in this chapter is “monitoring on-going development” which refers to the ability of looking for and understanding what the system and its environment doing (Pariès et al., 2012). To our knowledge there are no integrative models of work behaviour that relate to this cornerstone, however, we have identified a variety of well-known concepts that can be seen to be related to the monitoring cornerstone. These are: questioning attitude, sense-making, situational awareness and collective mindfulness. Questioning attitude is perhaps best known as a principle in nuclear safety culture and working practice literature: it refers to ability and disposition to notice and question unusual signs and occurrences, seeking guidance when in doubt, asking questions and questioning one’s own attitudes and actively seeking independent views (IAEA, 2008b; INPO, 2006). Questioning attitude is also one of the IAEA’s good safety culture attributes (IAEA, 2008b). Sense-making refers to the effort of understanding the connections between various elements in the environment and acting effectively (Klein, Moon, & Hoffman, 2006). Sense-making activities have been illustrated as, for example, organising chaotic inputs that stem from the working environment into meaningful information by means of interpretation, labelling and retrospection in order to carry out sensible action (Weick, Sutcliffe, & Obstfeld, 2005). A related concept is situation awareness, which refers to the perception of elements in the environment, understanding of their meaning and their future effect (Endsley, 1995). Situation awareness is a widely recognized concept in safety-critical organisations, especially in aviation domain. Finally, collective mindfulness refers to the capability to discover and manage unexpected events (see also chapter 2.2.6) (Weick, Sutcliffe, & Obstfeld, 2008).

In addition to the identification of various types of adaptive performance, there are some indications that different work contexts are more likely to involve particular types of adaptation in the literature. For example, job types in military have been found to be related to different types of adaptive performance: attorneys and recruiters were found to be most often involved with incidents in which interpersonal adaptability was demonstrated; dealing with uncertain and unpredictable work situations was most often demonstrated among infantrymen and executive assistants; handling emergency and crisis situations on the other hand was most common among air traffic controllers (Pulakos et al., 2000). The maintenance and use of nuclear power plants involves a heterogeneous variety of different types of tasks and job descriptions. The findings of Pulakos et al. (2000) suggest that workers at different jobs at nuclear power plants would demonstrate different profiles of adaptive performance. Extrapolating from the results of Pulakos et al.(2000), it would be reasonable to assume that, for example, nuclear maintenance staff that mainly carries out routine tasks with their own team, adaptations such as intercultural or creative problem solving might not be particularly prevalent – on the other hand interpersonal adaptability or procedure adaptation may be much more prevalent. Similarly, supervisors that manage outage activities may more often demonstrate such adaptive performance that relates to dealing with the inherent uncertainties of complex projects like outages, or dealing with the cultural multiplicity that stems from the multitude of 3rd party suppliers from different occupational, organisational or national contexts. The different prevalence of adaptive behaviours in occupational groups within maintenance is something to consider when attempting to capture adaptations in nuclear context.

2.1.2 Summary

Our literature review in adaptive task performance revealed insights that may help to operationalise performance adaptations that are the basis of the Resilience Engineering approach to safety management. Table 1 summarises the different facets of adaptive performance recognised in work performance literature. The categories presented in Table 1 are based on either the categorisation of Resilience Engineering literature (i.e. anticipation, monitoring, responding, and learning), with the exception of the category of tolerant, which was added because some types of adaptation didn't seem to directly fit the Resilience Engineering cornerstones that were discussed. The table is by no means a comprehensive framework of all types of adaptive performance, but rather a compilation of some of the best known conceptualisations of adaptive performance concepts, which may help the identification of adaptations in nuclear maintenance activities.

Table 1. Adaptive behaviours and abilities
(A = anticipate; M = monitor; R = respond; L = learning; T = tolerate)

Behaviour or ability	Description
Proactive personality[a] (A)	Individual's disposition to identify opportunities and act on them
Personal initiative[a] (A,R)	Taking an active approach to work and going beyond formal job requirements
Role Breadth Self-Efficacy[a] (A, R)	Capability of carrying a broader set of work tasks that extend beyond prescribed requirements
Taking charge[a] (A, M, R)	Willing to challenge status quo to bring constructive change
Socialization[a] (A)	Learning the behaviours and attitudes necessary for becoming effective organisational participants
Proactive feedback seeking[a] (A)	Proactively seeking information when facing uncertainty
Issue selling[a] (A)	Proactively influencing strategy formulation
Innovation[a] (A)	Production, adoption and implementation of useful ideas
Career management[a] (A)	Being active in one's career development
Questioning attitude[b] (M)	Maintaining vigilance and not proceeding under uncertainty
Sense-making[c] (A, M, R)	Understanding connections between various elements in the environment to anticipate and act effectively
Situational awareness[d] (M)	Perception and understanding of elements in the environment
Collective mindfulness[e] (M, R)	Awareness of discriminatory detail and a capacity for action
Handling emergencies or crisis situations[f] (R)	Adequate and urgent response in emergency situations
Handling work stress[af] (T)	Remaining calm and behaving adequately in stressful or busy situations
Solving problems creatively[f] (R)	Coming up with unique solutions to unseen problems
Coping with uncertain and unpredictable work situations[f] (T)	Behaving adequately in situations where complete awareness of the whole is not available
Learning work tasks, technologies, and procedures[f] (L)	Learning those skills and knowledge that are required to carry out tasks and actively participating in their further development
Demonstrating interpersonal adaptability[f] (T)	Being able to cooperate effectively with different types of people
Demonstrating cultural adaptability[f] (T)	Understanding and adjusting to the values, beliefs and orientations of those from other organisations, cultures or groups
Demonstrating physically oriented adaptability[f] (T)	Working in environments with extreme conditions such as heat, humidity or noise
Coping with organisational changes[g] (T)	Cope with and support changes done on organisational level
Procedure adaptation[hi] (M, R)	Identification of situations where procedures aren't applicable and adapting behaviour so that it reflects the actual conditions

Sources:
a) Crant (2000)
b) IAEA (2008b)
c) Klein et al. (2006)
d) Endsley (1995)
e) Weick et al. (2008)
f) Pulakos et al. (2000);
g) M. A. Griffin et al. (2007)
h) Gotcheva et al. (2013)
i) Reiman (2011)

2.2 The multidimensional nature of success

Safety-II thinking relies heavily on the notion of "success" as a starting point for analysis and learning. It appears, however, that there are no globally accepted models or practical definitions of "success" available in the existing literature. Simple dictionary definitions don't provide the sufficient concreteness required for practical purposes – a more thorough investigation into the different approaches to defining success is needed. There have however, been attempts to uncover various aspects to success in different areas of literature. We reviewed literature from the domains of leadership and project management, safety science and when possible, nuclear industry, to understand what is considered success from various points of view. This allowed us to compile an extensive set of criteria to identify successes.

2.2.1 Success as "non-failure"

One of the most common conceptualizations of success is "non-failure". This aspect to success suggests that anything that is not considered failure is a success. While logically valid assumption, depicting success as a mere complementary event to failure provides a too vague and abstract definition of success for operational contexts. In order to better connect the idea of non-failure to operational context, we carry out an exercise that involves introducing additional elements to form a more descriptive conceptual model and applying deductive logic to derive a list of different types of success situations – especially suited for operational contexts. This process is based on the following assumptions:

- There is a goal-oriented system that is in certain initial state
- The system holds expectations regarding its performance
- A task is performed over time
- The task affects the system state

By including these assumptions it is possible to generate a variety of situations that are based on the combinations of values of the following basic variables: time, system performance levels and expectation levels (Figure 1). In Figure 1 only those combinations that meet the requirement of "non-failure" (outcome not below expected performance boundaries) from the viewpoint of system outcome state are included, with the exception of "partial recovery success".

First combination, "neutral success", portrays a situation where the system is initially in an expected (normal) state and also after the task execution, remains in expected state. Practical counterpart of this combination would be when a task goes forth as planned and nothing of significant importance takes place. This combination is probably the most common situation in high-reliability organisations. Second combination is "extraordinary success" which starts from expected state yet progresses into something better than expected – system performance improves against some criteria. Third combination, "neutral extraordinary success" shows a situation where the system initially functions better than expected and after the execution of the task remains that way. This situation might be best characterised when a system is in a constant positive development and hasn't yet been able to normalize its development into expectations. The fourth combination is a "recovery success". In this situation the system is initially is a state of failure – below of what is expected of it. After task completion the system recovers from the failure and returns to within the expected state boundaries. A typical practical example would be a breakdown of a mechanical device that is then repaired by maintenance so that the device's functionality meets its required specifications again. Fifth situation represents "extraordinary recovery success" in which the system is recovered into state where it is above the expectation boundaries – for example when the machine would be repaired so that exceeds its original capability. Sixth combination, “partial recovery success” doesn’t actually meet the “non-failure” criteria because the outcome system state still remains below expectation boundaries. However, this situation may sometimes be a highly valuable and may demonstrate a positive trend – for example if a worse accident is avoided, partial functionality is restored or if the system otherwise manages make the best out of a bleak situation. Finally, the seventh combination, perhaps conflicting, is “negative success” – a situation where the system is functioning above expectations before task execution, but after task completion the performance drops, yet stays within expected boundaries. A practical example of this might be where a machine functions above specifications but after maintenance activities drops in performance but still remains within acceptable specifications.

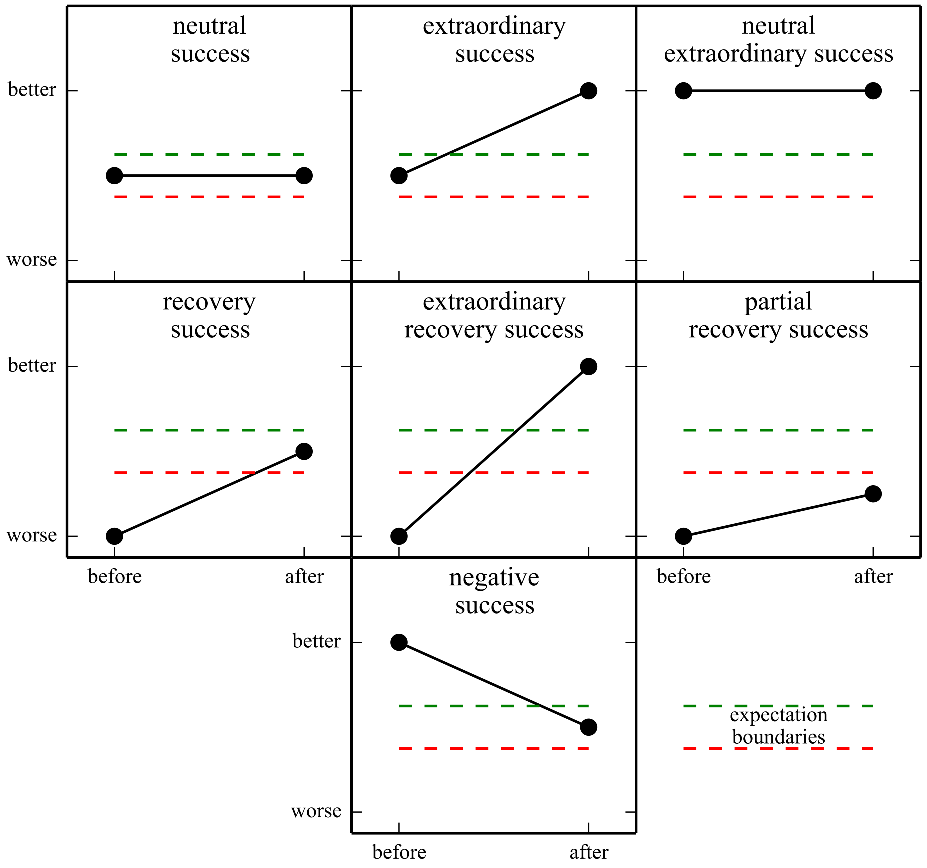

Figure 1. Combinations of “non-failure” performance. Each sub-plot of the figure represents a combination that has a before and after state of the system in relation to task progress on the x-axis. System performance level is on the y-axis. The red and green dashed lines represent the boundaries of expected performance for system states (for further discussion see subchapter 2.2.2). The black line shows the dynamics of system performance over time as the task is performed.

Another implication that this exercise illustrates is that success can be unexpected. All those combinations where the outcome state is outside expectation boundaries are essentially unexpected: the system experiences something out of the ordinary. If this unexpected event relates to positive performance, it can be considered as one of the “extraordinary” states: for example the system receives important insight to something or creates something new and innovative. Conversely, the unexpected performance that is below expectance boundaries would be considered a failure.

This exercise demonstrates that *successful task can take many forms in operational context even when the underlying criterion is merely based on "non-success"*. However, it also leaves many questions unanswered that affect success criteria in practical situations. Namely, how are the expectation boundaries defined, transmitted and interpreted and what are the variables against which system performance is assessed?

2.2.2 Expectation boundaries: multiplicity of stakeholders and goals

The previous examination of performance dynamics in task execution has defined success in relation to expectation boundaries: the system has certain "expectation boundaries" regarding its behaviour which then define success. These can be related to the concept of "aspiration level". Aspiration level is a point of reference that enables the dichotomization of performance into success and failure (Madsen & Desai, 2010). Greve (1998) provides the following examples of definitions of aspiration levels from various domains of literature: psychologically neutral reference point; smallest satisfactory outcome to the decision-makers; borderline between perceived success and failure. To emphasize "normal" performance levels that are neither significantly below nor significantly above the aspiration levels, two threshold lines are used in Figure 1 for illustrating the aspiration level, which is furthermore labelled "expectation boundaries" to underline the role of expectancy in forming the aspiration level.

The expectation boundaries are defined by the various decision-makers, or stakeholders (e.g. Wateridge, 1998). Stakeholders are generally seen as individuals, groups or organisations that are either actively involved with a project, or who have interests in the outcomes of the project (Baccarini, 1999). Quite often multiple stakeholders are involved. In nuclear maintenance activities a variety of stakeholders can be identified at different levels of the organisation and outside the organisation: maintenance shop-floor staff, foremen, supervisors, management, operators, planners and designers, licensee company, regulator, other governmental agencies and even general public. Stakeholders represent a variety of different groups that often have quite different perspectives on how something should be carried out and what the outcome should be like. This means that there may, in fact, be multiple expectation boundaries and multiple sets of variables of interest when it comes to assessing success: each stakeholder sets their own expectations from their perspective (McLeod, Doolin, & MacDonell, 2012). Respectively, there is a possibility of stakeholder disagreement where the project is seen as success from one's point of view and a failure from another's point of view. Furthermore, if the project or task is initially conceived on the basis of disagreeing stakeholder interests, it may lead to the formation of conflicting goals and conflicting success criteria, which needs to be managed somewhere down the line of the execution of the task.

In safety-critical organisations such as nuclear power plants, several "built-in" goal conflicts can be identified: some are on equal level of abstraction while others transcend the levels. For example, a same-level goal conflict is the juxtaposition between safety and productivity. An example of goal conflicts that transcends the level of abstraction is that of balancing higher-level goals such as safety, profitability, sustainability with the practical demands that allow to carry out the job at the lower level – this tension has been proposed as one of the main trade-offs in safety-critical organisations (Reiman, Rollenhagen, Pietikäinen, & Heikkilä, 2015). Reiman et al. (2015) argue that actions that relate to the local goals need to be aligned to the constraints set by the higher-level goals. This implies that the higher-level expectations need to be known, understood and considered by those that operate with the lower-level goals. This suggests that a distinction can be made between local success (e.g. achieving goals such as task completion) and systemic success (e.g. performing tasks in such a manner that plant safety or production is preserved; or achieving goals that improve safety).

The expectation boundaries also have a history-dependent, dynamic aspect to them. Cook and Rasmussen (2005) illustrate the change of system state over time with a concept of “flirting with the margin”. This concept elaborates the system migration processes as presented by Rasmussen (1997) by pointing out that the threshold of what is considered acceptable performance changes constantly as a result of the outcomes of previous actions (Cook & Rasmussen, 2005). An example of this in task context could be corner cutting when facing a demanding situation: a decision to move closer to the boundaries in order to achieve a result. Similar example would be putting exceptional stress on workers in order to achieve the task objective. If the results are perceived successful, it may cause the expectation boundaries (i.e. what is acceptable) to change and make similar behaviour more likely in the future (see also chapter 2.4.3): in relation to the previous examples, it would be thus accepted that corners are cut or stress is put on workers. From success point of view this means that the expectation boundaries are not static, and that they may sometimes move beyond what is actually desirable.

Even though the multiplicity of stakeholders may appear to imply that there is a certain level of subjectivity in the expectations (see also chapter 2.2.6), especially in highly-regulated safety-critical organisational such as nuclear power plants, a distinction can be made between mandatory and non-mandatory expectations. Some of the most obvious mandatory expectations are set by such authoritative actors as regulators, governments and the IAEA. In order to be allowed to operate, a licensee is required to adhere to and meet the conditions defined by these actors. This also applies to single tasks, especially those of nuclear safety significance. Therefore, one very essential criterion of success in nuclear industry activities is that they satisfy and adhere to the regulatory requirements. These requirements may involve either the process (i.e. how something is done) and/or the result (i.e. what is the outcome of the task). Especially in case of results, the regulatory expectations often define acceptability minimums, such as specifications of devices, radiation levels or doses. In this case, if success is assessed from the regulator’s point of view, as long as the minimum requirements are met, the task is successful.

Models of safety culture that provide a normative framework of what is acceptable or of good safety culture may also help define the “boundary” criterion for successful performance. Good safety culture is also required by either IAEA requirements (IAEA, 2006) or by national regulatory bodies in some countries (e.g. Finland; STUK, 2014a) which means that in nuclear context, achieving and demonstrating sufficiently good safety culture is not only a success in itself, but also a prerequisite for any activities. Safety culture has also been applied in identification of successful adaptations: in a study about local adaptations in nuclear maintenance, the adaptations were considered successful from safety point of view if they were carried out in such a manner that they didn’t violate good safety culture principles (Gotcheva et al., 2013). For this purpose, Gotcheva et al. (2013) applied DISC model of safety culture (Oedewald, Pietikäinen, & Reiman, 2011; Reiman & Oedewald, 2009), which includes normative criteria for attitudes or mind-set, organisational structures and understanding the nature of hazards that relate to job tasks. This approach to activity assessment essentially implies that a safety culture model could at least partially provide indicators that help define the relation between the activities and the "expectation boundaries" presented in Figure 1.

In conclusion, *universality or stability of expectations cannot be assumed for successful performance. What is considered success may be dependent on who is assessing the situation and from what perspective and at what time*. Thus, in practice, there are multiple "expectation boundaries". Therefore, it can be argued that there is no "the" success, just different types of successes, some of which are more mandatory than others. This suggests that in order to promote learning from successes, it may be useful to try to identify successes from many different perspectives.

2.2.3 Objective project performance approach

To better understand the nature of performance in the context of task-oriented activities, it is useful to review some general performance variables that are used to assess the extent of success. We apply insights from project management to identify some of the most interesting aspects of success. When adapting or re-interpreting these insights in the context of maintenance activities at nuclear power plants, a counterpart to the concept of "project" needs to be formulated. A project by definition is a temporary collaborative activity that is assembled in order to reach a beneficial objective (see e.g. Turner, 2009). In the context of this project we see the concept of "project" in a rather open-ended manner: it can be considered as a unit of activity that has a defined start and a defined stop. These units of activity can range from single tasks to extensive efforts such as outages.

Perhaps the most traditional way of approaching success is to consider it in relation to the immediate outcome. In early management sciences, this led to the use of so-called "iron triangle" criteria of success: cost, schedule and quality (i.e. meeting predetermined specifications) (see e.g. Atkinson, 1999; Jugdev & Müller, 2005). These criteria provide a simple and easily operationalizable framework for success criteria. However, these three criteria are geared towards short-term task outcomes and a success framework based on only these neglects a variety of other variables and approaches that are essential to other stakeholders than project managers (Atkinson, 1999; Baccarini, 1999; Bannerman, 2008; Davis, 2014; McLeod et al., 2012; Wateridge, 1998). To address this shortcoming, more comprehensive frameworks have been proposed. One of the more complete frameworks for defining project success has been proposed by Bannerman (2008). This five-level framework originates from IT domain and recognizes the following levels of success criteria:

- Process success
- Project management success
- Product success
- Business success
- Strategic success

Process success refers to the appropriateness of the methods, practices and solutions used for carrying out the project. Project management success refers to meeting schedule and cost requirements, and completing all stages within the scope of the project (i.e. the "iron triangle"). Product success refers to the main deliverable of the project meeting its requirements, including user satisfaction and impact. Business success relates to the extent to which the organisation meets its expected immediate benefits from the investment in the project. Finally, strategic success refers to the organisation gaining competitive advantage in the domain. In order to be useful in nuclear power plant context, we propose how this framework of success might be applied to stakeholders at nuclear industry (Table 2).

Each of the levels of success criteria can be seen to relate to different groups of stakeholders: project managers are interested in process and project management success, the end users' or clients interest lies in product success, the company or organisation benefits from business success and strategic success (Bannerman, 2008). This also means that typically success has meaning mainly within levels: stakeholders find that kind of success meaningful towards which they have interests (Bannerman, 2008). In practice this means that some stakeholders might not be aware of successes that take place at the other levels. For example, a project manager that is often naturally preoccupied with process and product management success might not consider the higher level successes – especially if failure has occurred within the manager's "own" level of success. Furthermore, Bannerman (2008) argues that the different levels of success are time-dependent: all levels of success are not available at all times of the project, but rather become observable over time. For example, strategic success might become observable only after several years after project completion. This makes it difficult for stakeholders that concern themselves with lower success levels to obtain feedback regarding the extent of success of the project at later stages. Such feedback might be especially relevant if those that operate on lower levels of the organisation have contributed significantly to the higher success levels – this suggests that in order to further nourish this positive contribution via, for example, learning from successes, awareness of the higher level successes should be ensured at the lower levels. It must be noted, however, that even though in Table 2 the example stakeholders move toward higher level of hierarchy as the level of success moves towards strategic success, also those workers or entities that operate on lower levels of the hierarchy experience time-scale dependent benefits: for example, an experience gained or lessons learned in one task or project may be manifested years later in the form of better knowledge. The levels of success are therefore not strictly bounded to hierarchical levels in the organisation.

Table 2. Bannerman's (2008) project success framework adapted to nuclear power plant maintenance

Level of success	Example stakeholders	Time scale	Description examples in nuclear maintenance
Strategic	Licensee	Several years after	Competitive advantage within nuclear industry, licensee growth or development, preparing for the future
Business	Licensee	Months-years	Expected benefits of the project to licensee met
Product	Plant, plant departments	Once delivered / implemented	Meeting product specifications, product becomes functional or accepted in its intended context
Project management	Management, supervisors, foremen	Immediately after completion	Meeting schedule, cost and scope requirements
Process	Management, Supervisors, foremen	Before or during execution	Applying best practices, adhering to procedures, fostering questioning attitude

There is also a possibility of a conflicted success: a project is successful on one level, but fails on another level (Baccarini, 1999; Bannerman, 2008; Wateridge, 1998) – acknowledging this possibility is one of the essential implications of multilevel success criteria frameworks. The example presented in Figure 2 illustrates a task that contains a coexistent success/failure system state: a task that goes out of schedule, yet remains within budget, and furthermore manages to produce a product that receives extraordinarily good acceptance among the end users. In nuclear power plant context an analogous example might be a maintenance task where schedule is not met, that doesn't otherwise require additional costs, but that manages to leave the device under maintenance in better condition than what was specified. This example can be interpreted to be successful on one level (product acceptance), neutral on another (cost), and unsuccessful on another (schedule). Acknowledging the possibility of conflicted success highlights the idea that even though there are obvious failures within the task or project, there may also be major successes – some which might get unnoticed due to the attention-catching nature of failures (see chapter 2.4.1). From learning from success viewpoint, applying multilevel success frameworks might be useful to identify which exact aspects of the task were successful, and then attending to the factors that led to the various types of success may provide important insights that have the potential to be beneficial in future performance.

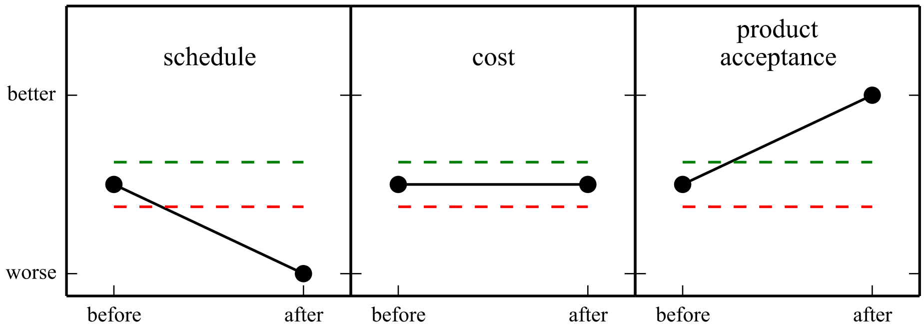

Figure 2. Multilevel success example that demonstrates a situation that is successful on one level but failure on another one

2.2.4 Safety approach

There is an extensive amount of literature in safety science regarding what indicators or performance measures can be used to operationalize “safety”. Broadly speaking, the operationalization of safety performance can be approached from two viewpoints: using outcome indicators or using leading indicators.

Applying outcome indicators is lagging by nature – the data only becomes available after an event has already taken place. Some examples of commonly used metrics in nuclear industry that relate to this approach are number of accidents or events, injury rates, number of INES events or scram rates, availability of safety systems, or number of near-misses (see e.g. Reiman & Pietikäinen, 2012). Systemic approach to the concept of safety management considers safety an emergent property or a potential (Leveson, 1995; Oedewald et al., 2011) – something that cannot necessarily be broken down to components or represented by a set of such as single outcome indicators. We acknowledge the problem of operationalizing safety by means of outcome performance indicators; however it is possible that when attempting to capture successful processes, using such measures as starting points for analysis may be useful. For example, acknowledging improving trends of outcome indicators as successes and directing attention towards them may trigger active and more profound learning processes that may help uncover what were the reasons behind these successful outcomes.

Attempting to understand safety performance using only lagging indicators is often discouraged because they are reactive by nature and may therefore not be valid for predicting future performance (Hopkins, 2009; Reiman & Pietikäinen, 2012). In order to better understand the real system state (i.e. safety potential) and its developmental direction in terms safety performance, leading indicators are preferred (Reiman & Pietikäinen, 2012). Usually the basis of leading safety indicators is a safety model that provides an understanding of the processes that lead to either safe performance or accidents. This understanding can then help pinpoint the factors that enable better future safety performance without having to rely on already realized accidents or events for providing data for safety development.

Safety models aren't commonly used to identify successful performances; instead they attempt to explain the process of how accidents can take place. Rosness et al. (2014) attempted to establish a distinction between successful and unsuccessful operations by analysing a selection of safety and accident models in order to find out what these theories – essentially failure models – imply about successful operations. To simplify this method, we apply similar approach to the three general categories of safety models as proposed by Hollnagel and Goteman (2004): simple linear models, complex linear models and non-linear models (see Table 3). Hollnagel and Goteman (2004) suggest that there is a particular type of goal that these models appear to strive towards: if we assume that goal-achievement is one type of success, the achievement of these goals could be interpreted as success.

Table 3. Implications of success by common types of accident models, adopted and modified from Hollnagel and Goteman (2004)

Accident model type	Failure (accident)	Success (safety)
Simple linear (e.g. Domino model)	Sequence of unfortunate events	Interrupting the sequence of unfortunate events
Complex linear (e.g. Swiss cheese model)	Combination of active errors and latent conditions	Removing active errors or latent conditions
Non-linear	Performance variability leads to undesirable outcomes	Controlling and monitoring performance variability

Simple linear models such as the Domino model (Heinrich, 1931) argue that accidents result from a sequence of events or factors that eventually lead to an accident. The implication of simple linear models is that safety is improved or ensured when this sequence of actions is interrupted. Therefore, from this perspective, a successful activity would be such that ensures that the sequence of these unfortunate events gets interrupted. Complex linear models such as Reason's Swiss Cheese model on the other hand argue that accidents take place as consequence of a combination of active failures and latent conditions (Reason, 2000). Active failures are, for example, "unsafe acts" (e.g. mistakes, lapses and slips) that are committed by people with direct contact with safety-critical systems (Reason, 2000). The effect of these acts is by nature immediate – yet it has short-lived impact on the system's defences as a whole (Reason, 2000). Latent conditions on the other hand are, as Reason (2000) describes, "pathogens of the system" that aren't immediately manifested and may stay hidden for long periods of time. These are commonly created by the "blunt-end" of the personnel such as designers, planners or managers (Reason, 2000). Some of the essential contributions of Swiss Cheese model is that it firstly highlights the existence of proximal and remote agents as contributing to events (Le Coze, 2013), and secondly it demonstrates that the types of contributing factors and their effects differ in time-scale. Therefore there are two types of implications of complex linear models in terms of success. Firstly, success can be considered as simply managing to avoid active failures. Secondly, success can be considered as a situation when adverse latent conditions are removed or weakened. Similar conclusion was made by Rosness et al. (2014) who suggested that success could be considered as the maintenance or creation of an effective barrier structure so as to avoid adverse consequences. These two types of success have certain similarities with the success criteria that were presented project management frameworks (see Table 2): they highlight the existence of time-correlated success (i.e. success can be related, on one hand, to long-term or "latent" conditions, and on other hand to immediate impacts) and that there are different stakeholders that operate on different levels of the activity (i.e. design or manage vs. perform) and that they get their feedback on different time-scales (i.e. create or maintain latent preconditions vs. directly affect the operating system).

Non-linear models emphasize the importance of performance variability as a source of safety (see e.g. Hollnagel, Woods, & Leveson, 2007). These approaches argue that safety-critical organisations are complex and are in a constant state of change and thus the approach to safety management requires constant adaptation to environmental factors in order to sustain the system's functionality. According to this approach, failures happen if the performance variability is, for whatever reason, unable to cope with the environmental changes or if mal-adaptation takes place. Conversely, successes happen when the system manages to adapt to its environment and thus performance variability has a positive effect on the system. The implication of this type of models in terms of success is therefore to focus on the control and monitoring of the performance adaptations and ensure that such adaptations take place that result on positive outcomes. Table 3 summarizes the three accident model types and their implications regarding success in safety-critical organisations.

The approach that emphasizes performance variability to sustain system functionality also brings out a question regarding the desirability of adaptation. Compensatory behaviour to unexpected demands doesn't come free and has expenditures such as additional workload, knowledge, expertise and worker allocation costs, and also financial and efficiency losses (Woods & Wreathall, 2008). From this it could be inferred that such task outcome that is achieved with least amount of compensatory effort from either the participating personnel or other parts of the system is the most successful one: in successful task performance smaller amount of extra effort is required of the system to keep itself in line with its core functionality requirements. However, if the system is considered as something that is dynamic and continuously adapting, a situation of non-adaptation might not be possible as small adjustments are always being made. From single task performance point of view, therefore, those adaptations that cause least amount of effort from other parts of the system would be the most successful ones. A simple case of system's compensation could be, for example, if a task team, after noticing that they lack a tool to carry out a job, decide to borrow that tool from another team in order to keep schedule. This team might succeed in their on-the-spot adaptation, but it might put stress on the other team, requiring them to adapt to the lack of the tool. The initial local strain could therefore be reflected in other parts of the system. When assessing successes and successfulness of adaptations, it is therefore important to consider the systemic effects of the adaptive behaviours and pay attention to the wider effects of decisions of the local agents.

Something to consider is that events also have a systemic and emergent aspect to them. For example, Rasmussen (1997) argues that accidents are the result of a natural migration of the system within its state space: from this point of view, there might not actually be specific failure behaviours, but the failure rather emerges as the system state changes over time. From this it could be therefore inferred that success is related to the system being able to retain its state within acceptable state space boundaries and avoiding drift towards unacceptable boundaries. On task level, from this viewpoint it could be argued that all task outcomes or processes that cause the system to migrate away from the boundaries and help manage the trade-offs between the boundaries are successful.

In addition to abovementioned safety and accident models, organisational models have also been used to explain accidents. Organisational models imply that the organisations drift to failures due to such activities as development of routines and simplifying and optimizing of activities (Reiman, 2015, p. 12). One of the most common organisational models of safety in nuclear industry is safety culture which can be interpreted as a measure of the organisation's potential for safe activities. For example, the DISC model of safety culture (see e.g. Oedewald et al., 2011; Reiman, Pietikäinen, Oedewald, & Gotcheva, 2012) describes three types of normative criteria that need to be achieved in order for an organisation to have a "good safety culture". These criteria are mind-set (e.g. attitudes, responsibility, safety as an important value), organisational structures (e.g. creating preconditions for working in a safe and manageable way) and understanding the hazards that are related to the activities (Oedewald et al., 2011). The basic assumption of safety culture theories is that if the culture doesn't meet desirable characteristics, it will manifest itself in undesirable behaviours or structures that eventually make an accident more likely. Respectively, it can be inferred from this that a successful organisation from safety culture perspective is such that continuously manages to maintain or improve its culture – actions or decisions that result in improved safety culture could therefore be considered successful.

Finally, the abovementioned safety models don't explicitly include the notion of different types of safety. Nuclear power plant maintenance is involved with many types of activities and safety-critical systems that create a variety of different types of hazards. The subtypes of safety include, for example, nuclear or process safety, environmental safety, occupational safety and radiation safety. The safety subtypes differ from each other depending on what is the main hazard and who or what is threatened by that hazard. Consequently, different mechanisms affect each safety subtype. Therefore, a successful state in a particular safety subtype doesn't necessarily imply a success in another: sometimes the safety subtypes may even be at odds, for example if maintaining a safety-critical device requires an increased exposure to radiation. In this situation there is potential for a "conflicted success" where there are no obvious answers. This creates a trade-off situation which requires prioritisation and weighing the relevance of different types of safety.

In nuclear industry, the success of many maintenance activities will be affected by how safe the process or outcome the task has been. Both simple outcome indicators and complicated models can be used to approximate safety performance in a given situation. Each of the methods captures some aspect to safety that can be useful in identifying successes. Some safety models emphasize the relevance of systemic interactions and the complexity of safety-critical organisations. This is something to be considered when outcomes are labelled successes: *a systemic approach that considers the dynamic interconnections between the various actors in the organisation may be necessary before the successfulness of a process or outcome is concluded in order to avoid simplified judgements.*

2.2.5 Contingency approach

As a reaction towards the traditional approaches to success that have considered success as a strictly objective or rationalist property, there has been an increasing interest towards alternative ways of conceptualizing success. Conceptualizing project success merely by means of predetermined objectives has brought up multiple problems that may render such metrics ineffective in some situations. For example, all situations might not be conceivable beforehand and thus predetermined goals may not reflect reality, or the understanding of success may be affected by human and social behaviours. Ika (2009) reviewed literature in project management sciences and provided with two alternative approaches to the traditional, objectivist success criteria: contingent approach and constructivist approach (see chapter 2.2.6).

Contingent approach proposes that attempting to find universal and globally accepted criteria for success is likely to be futile and that success might be better conceptualized in relation to specific situations or project types (Dvir, Lipovetsky, Shenhar, & Tishler, 1998). Ika (2009) summarizes this approach by emphasizing that success is in relation to situational and context-specific factors. In addition to the common contingencies presented in chapter 2.2.3 (e.g. time of assessment, assessing stakeholder), a potentially relevant factor to nuclear maintenance that may affect the relative importance of various types of success is "technological uncertainty" (Shenhar, Dvir, Levy, & Maltz, 2001). Shenhar et al. (2001) studied success criteria identified by project managers in various contexts ranging from "low-tech" projects that rely on existing and well-established technology (e.g. construction of buildings), "medium-tech" projects that incorporate new technologies or features (e.g. designing new versions of existing technology), "high-tech" projects that create new technologies (e.g. completely novel solutions or introduction of new systems) and finally "super high-tech" projects that are based on technologies that don't exist at all before the project initiation (e.g. developing systems to function in unknown environments). Shenhar et al. (2001) observed that the success of lower-tech projects is more often assessed by efficiency measures such as schedule or cost – these projects are expected to produce standard outcomes and are commonly not expected to provide preparation for future. Respectively, in case of high-tech projects, overruns are more acceptable; outcomes are less standard but are expected to provide preparation for the future (i.e. strategic-level success as presented in Table 2). In nuclear power plant maintenance there are a variety of different types of activities ranging from simple and routine everyday tasks (akin to "low-tech" projects) to rare and extraordinary overhaul projects (akin to "high-tech" projects) or in, for example, new-build projects even development of completely new solutions (akin to "super high-tech" projects). Shenhar et al. (2001), just like most other project management studies regarding success criteria, see the criteria as something that help project managers to better assess project state. We propose that in addition to that, success criteria can also be used to identify where to look for lessons. Therefore, drawing from the findings of Shenhar et al. (2001) it can be suggested that the most important lessons to be learned from successes would emerge from those aspects of the project that relate to the most relevant success criteria. For example, in case of a basic maintenance task (e.g. replacing a valve), one would apply the success criteria common for that level of task (e.g. schedule, cost, quality) and the lessons would be extracted from the contributory factors that led to the achievement of these success criteria. Similarly, in case of a high-tech project (e.g. new-builds or major overhauls), the most relevant lessons could arise from scrutinizing the factors that enabled the strategic level of success criterion to be met. However, even if a simple maintenance task doesn't need to provide strategic-level advantage to be successful, if for some reason it does, one should be sensitive to that to extract useful lessons.

In addition to the outcome of the task, contingency approach also implies that there may be multiple ways to achieving the task. Ika (2009) suggests that from contingency viewpoint, success is something that doesn't involve a Taylorist "one best way" for achieving success. Operations at nuclear power plant maintenance are typically heavily proceduralised and pre-planned. Adhering to this process can itself be considered a success as is also implied by some aspects of the multilevel success criteria frameworks presented in chapter 2.2.3. Taylorist approach to goal achievement would argue that the procedures represent a perfect way of doing things and that merely following them inevitably leads to successful outcomes. In case of stable, predictable and known systems this approach is more likely to be valid than in dynamic contexts. Contingent approaches on the other hand argue that there is, in fact, not only one way of doing things and that multiple paths can lead to successful outcomes. In this sense, contingency approaches acknowledge the uncertainties involved in carrying out activities. This has implications towards process success: the mere following of standard procedures might not be sufficient to ensure that the outcome of the task is successful, especially if there are any contingencies in the environment. For example, in a study about the application of human performance tools in nuclear maintenance it was found that the tools were perceived beneficial in some situations and useless – sometimes even detrimental – in other situations (Oedewald et al., 2014; Oedewald, Skjerve, Axelsson, Viitanen, & Bisio, 2015). Some of the negative aspects that were identified concerned, for example, personnel becoming robotic and over reliant on procedures (Oedewald et al., 2014). The researchers concluded that human performance tools are most likely to be beneficial if they are implemented in such a manner that their situational application would be possible (e.g. in situations that are complex and there are risks, or when the tool is readily well-adapted to the situation and doesn't require extra time or when the workers feel it is natural to use the human performance tool) and that the tools are well-integrated and don't confound with existing practices (Oedewald et al., 2015; Skjerve & Axelsson, 2014; Viitanen, Axelsson, Bisio, Oedewald, & Skjerve, 2015).

2.2.6 Constructivist approach

A more radical breakaway from rationalist approaches is presented in the form of constructivist approaches to success. This is a major change in focus and paradigm which argues that success is a socially constructed concept and emphasizes meaning and interpretation (Ika, 2009; McConnell, 2010). McLeod et al. (2012) further elaborates that constructivist success criteria are based on stakeholder expectations (see also chapter 2.2.2) and that the expectations are derived from their value-based beliefs and desires regarding what best serves their interest – this leads to success being a constructivist construct.

In safety-critical organisations one of the best-known manifestations of constructivism is organisational culture (esp. safety culture) which has been one of the mainstays in "soft" nuclear safety since late 1980's. Safety culture has been characterised as the cultural patterns that guide and "choreograph" all activities in the organisation, manifesting itself through organisational structures, working practices, group processes and daily-decision-making (Oedewald, 2015, p. 14). In terms of success, organisational culture can be assumed to have an effect on how successes are constructed, for example through steering the way judgements are made, how assessments carried out and what kinds of expectations are set for tasks.

Another constructivist approach that may affect how activities are perceived and assessed is collective mindfulness as proposed by Weick and Sutcliffe (2007). Collective mindfulness is a group-level variation of the individual "mindfulness" thinking that manifests itself as a continuous scrutiny of existing expectations, refinement of expectations through experience in order to improve future functioning (Weick & Sutcliffe, 2007). In practice, heightened collective mindfulness is assumed to result in richer repertoire of actions due to the mindful observations made by the group; furthermore, this leads to a better potential for future preparedness for unexpected events (Weick et al., 2008). From collective mindfulness viewpoint, success can be considered a variable state that is the result of the actions of those individuals or groups that have managed to profoundly observe and understand their environment: the group constantly changes their expectations regarding the system and thus their understanding of successful outcomes changes, as does their action repertoire, which furthermore changes the system they interact with. From learning point of view, this approach would suggest that it might be useful to identify the "mindful" individuals or groups because they may have profound insight to how the system functions, and respectively, how successful activities are achieved in their daily work.

Cuellar (2013) includes organisational power-relations into the definition of success and argues that success relates to the adaptation of a structure within the organisation. More precisely: "*When a sufficiently influential social agency is able to impose upon, persuade, or negotiate with the other social agencies so that they adopt the idea that the project is successful*" (Cuellar, 2013, p. 13). This approach emphasizes power-struggles and negotiation between the various stakeholders in defining and judging whether something has been successful or not. In nuclear industry a version of this kind of process may take place between regulators and licensees. For example, in situations where a design needs to be approved, the licensee is required to produce sufficiently thorough documents to present to the regulator. The acceptability – or success – of the design is therefore dependent on how good "safety case" the licensee is able to make to the regulator; sometimes this process may be complicated and lengthy – even simple modification jobs may require months of discussions and document exchange with the regulator (see e.g. M. Wahlström, 2015). Furthermore, the topic of power is brought up by Antonsen (2009) who re-analysed the decisions behind the failed Challenger space shuttle launch from the perspective of power relations and demonstrated the various processes of power-conflict where, for example, the warnings or concerns of various technological experts were disregarded or overruled. The implication to success is therefore that organisational power-relations have the potential to dictate what is considered successful or desirable, which may also mean that sometimes the success criteria are narrowly defined by those stakeholders that have most power.

2.2.7 Summary

In this chapter, the dynamic aspect of success has been brought up in several occasions: the extent to which something has been successful may change over time (Table 4). This can include, for example, situations where a task that has previously considered a success is later found out to be a failure, or a delayed recognition of success. In nuclear maintenance it may not always be possible to update the information about previous tasks if changes have occurred. For example, once the team moves to another task or a 3rd party leaves the plant after outage, it may be difficult to gather everyone back together and reflect the situation in light of the new information. Because of these practical issues, changes in the extent to which a task was successful from some perspective may not be reflected to everyone that was involved with the task. This may mean that the lessons learned may be based on incomplete information or they may be obsolete. In addition, people may demonstrate bias towards initially learned information and may consider knowledge gained after-the-fact less valuable (see e.g. "anchoring bias"; Tversky & Kahneman, 1974), which is something that should be deliberately addressed. This suggests that when attempting to identify and promote successes as a source for learning, it may be useful to also consider what are the dynamics of success; i.e. how does the understanding of success change over time. Table 4 summarises the dynamic aspects of the approaches to success as discussed or implied in previous chapters.

Table 4. Dynamic aspects of success

Dynamic	Description
Change in criteria	The criteria against which success is assessed against changes over time
Change in stakeholders	The relative importance of satisfying a particular stakeholder changes as time progresses
Change in outcome	Outcome that was initially thought successful turns out to be failure, or vice versa; e.g. the true status of a redundant of rarely used device is found out a long time after the maintenance task is performed on it
Change in expectations	Expectations set for the task change during the execution of the task
Change in environment	Environmental factors change during the task
Change in subjective constructions	Subjective or socially constructed conceptualizations of what is “success” or “failure” are in a constant state of change and development

In this chapter we have identified and discussed a variety of different approaches to success both in regular and safety-critical organisations. Success is a multidimensional concept that may manifest itself in a variety of different ways. Below we propose a summary of the most relevant findings in our review:

- Success in task-oriented activity is the extent to which the system change induced by a task matches the performance expectations set for the system
- Success relates to the system’s performance expectations which are defined both objectively and subjectively by a variety of different stakeholders, some of whom may have more weight to their opinions than others
- Success has both normal (as expected) and non-normal (better than expected) qualities
- Success can take many forms: success can be an extraordinary innovation, carrying out of a daily routine, recovery from a failure or changing the direction of an adverse trend
- Success is relative to task characteristics: demanding or complicated contexts tend to have different success criteria than routine contexts
- Assessment of success is time-dependent: depending on the nature of the task or its impacts, some aspects of success may become available much after the task completion
- Safety is success: adhering to safety requirements and maintaining or improving the preconditions for safe activities is a prerequisite for safety-critical organizations
- Success is systemic: local, partial and conflicted successes may take place, however, the overall functionality of the organization requires a systemic approach

2.3 Organizational learning

Creating new knowledge, disseminating essential know-how and developing competences are important aspects to sustaining the functionality of an organization. Learning in an organization is both a necessity and a consequence of changing operative conditions. An organization, in order to survive and thrive, has to find new ways to face or exploit changing external conditions (for example, when new technology is made available) or its internal dynamics (for example, employee turnover). In order to better understand how an organization identifies, analyses and implements lessons learned from successes, we have reviewed literature in the field of organizational learning. To apply the concept to practice, in this chapter we discuss briefly how experiences can increase organizational knowledge and how individual learning relates to organizational learning – or more specifically, how lessons learned at individual level can be integrated into organizational activities. In addition, we examine the role of operating experience as a mediator or facilitator of organizational learning in the context of nuclear industry.

2.3.1 Concept overview

Research into the concept of organisational learning attempts to create an understanding of how learning takes place in organisations. Organisational learning has been studied within many disciplines including sociology, economics, anthropology, educational psychology, management sciences and organisational sciences. There are many definitions for organisational learning, but over the years a certain level of convergence has been observed: commonly it is agreed that organisational learning could be defined as a "*change in the organization's knowledge that occurs as a function of experience*" (Argote, 2013, p. 31). The concept of "knowledge" in this definition includes both declarative knowledge such as facts (i.e. explicit knowledge) and procedural knowledge such as skills or routines (i.e. implicit knowledge) (Argote, 2013, p. 31).

Argyris and Schön (1992) distinguish two basic types of organisational learning processes: single-loop learning and double-loop learning. When applying single-loop (a.k.a. adaptive) learning, unexpected consequences of an action are detected and compared to underlying assumptions, and then the unexpected consequence is corrected. Double-loop (a.k.a. generative) learning goes further by changing the underlying assumptions that are related to desirable consequences. Single-loop learning is a mechanical and simple process that is focused on solving specific problems (e.g. a thermostat attempting to keep a temperature) while double-loop learning is a more complex and fundamental process that attempts to create novel solutions (e.g. redefining the desirable temperature). In organisational context, double-loop learning would relate to changing the basic goals, beliefs or values while single-loop learning would relate to carrying out the daily routine work.

Organisational learning can also be seen as comprising of three information processing stages: creation, capturing, transfer and retention of knowledge (Figure 3) (e.g. Argote, 2013). This means that learning is essentially a continuous cycle that is triggered by experience and that results in changing of the next experience. Each stage has enabling factors and limiting factors, supporting techniques and technologies, analysis methods and indicators. The stages can occur at a very different time scale, for example in case of on-the-job training, when a more experienced person trains a novice (i.e. long-term cycle), or when observations on the field reveal a weakness of the production process and suggest a solution to overcome it (short-term cycle). The type of knowledge can also vary a lot, in terms of its content, how it is formulated, how it is transferred, to whom or to what it is transferred, the level of abstraction and generality, and the significance of its impact.

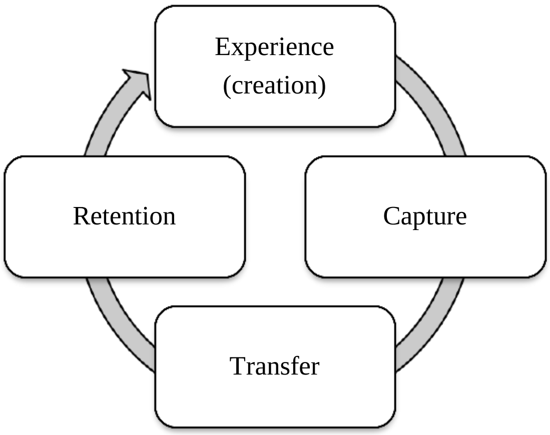

Figure 3: The phases of organisational learning. Experience is based on the current competences or conditions; it can involve the creation of knowledge and innovation. In order to change the future experience (i.e. learn), the current experience needs to be observed and pieces of knowledge or competence need to be noticed and captured. Those "pieces" can be new knowledge, transformed knowledge, operationalization of more abstract concepts, new practices, but also already present, implicit knowledge, that until now has been owned by only a few. Once recognised as worthy to be shared, the relevant knowledge can be transferred and distributed. Retention is the phase that allows the knowledge to be used to change the future experience, creating an impact on the performance of the organization.

2.3.2 Types of knowledge

Organisational learning processes can relate to different types of knowledge. Commonly a distinction is made between explicit and tacit or implicit knowledge (see e.g. Nonaka, 1994). Explicit knowledge exists in codified form (e.g. documents, databases, written procedures, etc.), and can be transmitted either verbally or in writing (Nonaka, 1994). Conversely, tacit or implicit knowledge cannot be articulated or expressed as such, but it is rather something that relates to elements such as crafts, skills or beliefs (Nonaka, 1994; see also Polanyi, 1966). This also means that the transfer methods and strategies are different depending of the whether the knowledge is explicit or tacit.

One of the most well-known theories of the relation of tacit and explicit knowledge in organisations is the theory of knowledge conversion as proposed by Nonaka (1994). This theory illustrates how different types of knowledge can be transferred and converted. The following four modes of knowledge conversion are distinguished by Nonaka (1994):

1) Tacit → tacit (socialization)
2) Tacit → explicit (externalization)
3) Explicit → explicit (combination)
4) Explicit → tacit (internalization)

The first mode (socialisation) involves transferring existing tacit knowledge forwards. This kind of learning takes place when individuals interact and it can be non-verbal (Nonaka, 1994). Common examples of this could be a mentor-apprentice relationships (Nonaka, 1994), or more generally, being or spending time together in the same environment (Nonaka & Konno, 2005). The second mode (externalisation) involves knowledge conversion from tacit to explicit. This makes tacit knowledge more available to others. This type of knowledge conversion involves the articulation of tacit knowledge through means such as storytelling, or using metaphors and analogies (Nonaka & Konno, 2005). The third mode (combination) combines existing, explicit information to create new knowledge through, for example, sorting, adding and re-categorizing (Nonaka, 1994). This may involve, for example, collecting information from explicit sources, disseminating the information through meetings or presentations, and processing the information to formulate plans, reports or procedures (Nonaka & Konno, 2005). The third mode (internalisation) converts knowledge that exists in explicit form into tacit. According to Nonaka (1994), this mode relates most closely to traditional understanding of “learning”: this type of learning occurs when explicitly available information becomes part of the learners’ tacit knowledge base. This may involve learning by doing, and participating in training and various exercises (Nonaka & Konno, 2005). Overall, this model of knowledge conversion provides insight to how different types of knowledge are exchanged and transformed within the organisation.

2.3.3 Connection between individual and organizational learning

Organisational learning processes can have different scopes and they involve different agents – hence they may function at different levels of the organization: Individual, team, organizational and inter-organizational (e.g. Argote, 2013, p. 20). For example, operating experience activities at nuclear power plant have both inter-organizational and intra-organisation scopes: developing one’s own plant, but also contributing to the whole industry by means of sharing knowledge with other plants.

From organisational learning viewpoint, individual learning can be seen as the smallest unit at which learning can occur. Individuals learn, and as they gain expertise, the organization’s performance changes. However, if the experience remains in individuals, and it is not embedded in the organization, it will follow people. Individual learning does not guarantee organisational learning. Therefore, more systematic capturing, transfer and retention of knowledge is necessary.

For Senge (1990), the fundamental learning unit is team. Working team can include persons from different organizational units, and in case of a nuclear power plant, especially in maintenance activities, the team can also include people from third parties. At group level learning could happen when one individual shares his or her knowledge with other members in the group or when individuals learn how to work together as a team. Senge considers team learning as one of the five disciplines that an organization needs to master to become a learning organization: “*unless teams can learn the organization cannot learn*” (Senge, 1990, p. 12).

At the level of organization, when the knowledge is retained in the organization’s memory, it becomes embedded in the organization: technologies, structures, practices, routines, values or in the culture. Organizations can also exchange their experiences with other organisations (i.e. inter-organizational learning), which provides a larger knowledge base. Inter-organizational learning is quite common practice in the nuclear industry, especially in the aftermath of incidents, when lessons are widely spread and shared not only between operating nuclear power plants but also with organizations like regulatory bodies.

While organisations ultimately learn via their individual members, their internal groups, and sharing experience between organisations, the three levels of learning must be integrated to achieve effective organisational learning. Several theoretical models of organizational learning have been developed from the perspective of diverse disciplines. One of the most influential models is the 4i model (Figure 4) (Crossan, Lane, & White, 1999). The 4i model proposes that organizational learning occurs through four dynamic processes: intuiting, interpreting, integrating and institutionalizing. The intuiting process involves individuals perceiving patterns and possibilities (e.g. expert intuition); this is seen largely as an unconscious process (Crossan et al., 1999). Interpreting is a process of verbalising “hunches”, feelings or expert insights; this also allows explicit connections to be made between the bits of information (Crossan et al., 1999). Integration occurs when the information interpreted by the individuals becomes part of the collective knowledge of a group; this process involves, for example, dialogue between the group members (Crossan et al., 1999). Finally, the process of institutionalisation is when the knowledge gathered by individuals and groups is embedded to organisational elements such as structures, procedures and strategies (Crossan et al., 1999). One of the main underlying reasons behind institutionalisation is exploiting the knowledge is a systematic manner. These four processes move, through the three organisational levels: from the individual to the organizational (feed forward; i.e. collecting new information) and from the organizational to the individual (feedback; i.e. exploiting what has been learned) (Crossan et al., 1999).

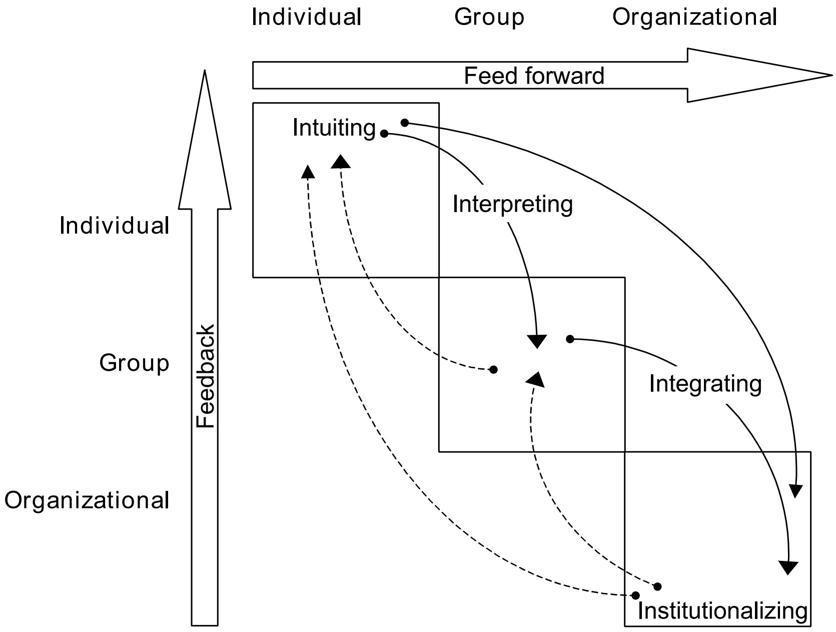

Figure 4. The 4i model of organisational learning integrating the three levels of learning (Crossan et al., 1999).

2.3.4 Operating experience and organisational learning

In the nuclear industry safety is of the utmost importance and therefore safety plays a central role in judging the performance of a nuclear power plant. Demonstrating good safety culture in operations can be considered a prerequisite for safety. IAEA (1991, p. 1) defines good nuclear safety culture in the following manner:

> *“Safety culture is that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance.”*

To build and maintain good safety culture an organisation should exhibit certain characteristics. Many safety culture models that are commonly applied in the nuclear industry emphasize the relevance of learning. For example, IAEA states that one of the characteristics of good safety culture is that “safety is learning-driven”; this characteristic is further elaborated via attributes such as having questioning attitude, encouraging open reporting, using operating experience, learning through recognizing deviations and formulating corrective actions and developing individual competencies (IAEA, 2008b, p. 29). Likewise, INPO (2004) emphasizes the relevance of embracing organizational learning in their conceptualization of safety culture. WANO (2013), on the other hand, considers learning as one of the basic traits of a management system for supporting a healthy safety culture: opportunities to continuously learn should be valued, sought out and implemented. In particular, the first attribute of the continuous learning principle states (WANO, 2013, p. 8):

> *"Relevant internal and external operating experience is systematically and effectively collected, evaluated and lessons learned are implemented in a timely manner by the organisation."*

Furthermore, learning activities are, to some extent, regulated by many authoritative organisations such as the IAEA or national regulatory bodies by defining the recommendations or requirements for operating experience activities. For example, IAEA provides best practices for organizing, managing and conducting an event investigation (IAEA, 2008a) and includes a requirement for a system for reporting feedback from events in its safety standards (IAEA, 2006). Finnish nuclear safety authority, STUK, has defined general guidelines regarding how to proceed from the moment an event takes place, to investigation of the event and formalization of the report (STUK, 2014b). In addition, sharing experiences with other organizations in the industry, and requiring the licensee to provide appropriate objectives, structured procedures, adequate resources and full support of the top management are required (STUK, 2014b). In the USA, the Department of Energy has issued an "Accident and Operational Safety Analysis Handbook" (DoE, 2012a, 2012b) with the intent to organize the current knowledge on incident models involving technical, human and organizational factors, to improve the practices of accident investigation and operational safety reviews. In addition, this handbook provides detailed process and guidelines for accident investigation.

On paper, the abovementioned guidelines, principles and regulations demonstrate a commitment to learning activities. In addition, the existence of various formal systems for sharing knowledge between plants (e.g. peer reviews, IAEA and WANO activities) can be considered facilitators for organisational learning in the nuclear industry (B. Wahlström, 2011). However, the existing learning practices appear to be somewhat limited in scope. In a study of nuclear operating experience activities and organisational learning, it was found that currently nuclear operating experience focuses on event analysis and planning of subsequent corrective actions – effectively reactive, single-loop learning (Oedewald, Pietikäinen, & Haavisto, 2010). Oedewald et al. (2010) note that single-loop learning may be useful in providing remedies for the most obvious errors, however, its benefits may be limited when it comes to developing general prerequisites for safe activities. In summary, while the relevance of the operating experience activities is then generally agreed upon, the focus of the operating experience appears to be mainly on reactive learning from failures.

The organisational units responsible for operating experience can be seen as agencies that either carry out the learning process themselves, or that create the preconditions for learning in the organisation through facilitating organisational learning activities. These roles can be further elaborated by relating operating experience activities to the organisational learning theories discussed earlier in this chapter. Most commonly operating experience activities appear to be engaged in collecting and storing information, or planning and implementing organisational changes. This relates most clearly to the institutionalisation phase of the 4i model of Crossan et al. (1999): the information embedded in the organisation is captured, structured, systematized, and brought to organisational knowledge bases for future use. Usually the information sources used are interviews and written documents, which, when related to Nonaka's (1994) knowledge conversion model (briefly described in 2.3.2), would suggest that the activities are mostly focused on production of explicit information (e.g. verbal or written information are combined to create new verbal or written instructions or procedures). In practice, focus on this type of learning manifests itself as a strong culture of codification and report creation in operating experience activities, while perhaps overlooking other aspects of organisational learning.

Operating experience activities in nuclear power plants use a considerable portion of time and effort on creating various reports that are either required either by the company policy or the regulator. Mostly these requirements relate to events, incidents or other failure situations. In practice this may mean that those activities that are not directly required by any authoritative body are more likely to be either neglected or are difficult to realize due to resource limitations. The Safety-II approach (i.e. putting focus on understanding successes) as suggested by Resilience Engineering tradition doesn't readily seem to provide a convenient solution to the very problem that it creates: when focusing on the 9.999 successes out of the 10.000 events instead of 1 failure out of 10.000 events, a much larger database for analysis is formed – but how could an organisation which also needs to ensure its production objectives and meet the requirements of analysing the failures in any case, find enough resources to also perform the analyses of normal or successful events? *In order to make Safety-II feasible, the industry practitioners would require means that allow them to better manage the massive amount of data, or assume another strategy to learning than codification.*

Managing the massive amount of data could be addressed, for example, through the following strategies:

- *More effective selection*: e.g. narrowing the scope of success examination to most critical tasks, or to those situations that are generalizable or of relevance to one's own plant
- *More effective analysis methods*: e.g. integrating light and non-intrusive "success analysis" methods to established event investigation practices
- *More efficient information technology*: e.g. creating innovative technological means to handle the massive amount of data and utilizing them to extract lessons learned from successes

Operating experience activities can also be involved in supporting other types of learning than institutionalization or production of explicit knowledge. For instance, considering various implicit or social processes that relate to learning or creating preconditions for organizational learning processes that involve implicit or tacit dimensions could be beneficial when attempting to capture, analyze and retain lessons learned from successes. This is especially important considering that often the lessons learned from successes may be embedded tacitly in the organization (e.g. Madsen & Desai, 2010).

Overall, *organisational learning models may provide insights to the development of operating experience activities*: for instance, which organisational learning processes are managed actively by the operating experience activities and which are in need of further development, and what practical methods could be applied. In addition, organisational learning models and principles created specifically for nuclear power plant organisations (e.g. Kuronen, Säämänen, Järvenpää, & Rintala, 2007; B. Wahlström, 2011) can be beneficial for understanding and developing operating experience activities to better support organisational learning from successes.

2.3.5 Summary

The concept of organisational learning aims at understanding how organisations, through experience, change their behaviour by adapting to a changing environment and exploiting its resources in an innovative way. Organisational learning can also refer to the collection of learning processes inside the organisation. Organisations learn, almost in a natural way, but not all have the same ability to exploit their environment, or the ability to complete the learning cycle, or the ability to learn the right things. Managing and developing organisational learning is essential in order to sustain the organisation's performance and avoid unexpected outcomes.

Operating experience is one of the best-established existing structures in nuclear power plants that can be utilized to develop organisational learning processes and systematic learning from successes. This can include, for example, active learning processes initiated by the organisational unit that is responsible for operating experience activities, but also creating preconditions for learning in others parts of the organisation. Furthermore, applying organisational learning theories to identify the strengths and weaknesses of the learning activities in power plants may be useful when developing operating experience practices and real-world methods.

2.4 Learning from successes and failures

Even though Resilience Engineering tradition makes a plausible case regarding focusing on successes instead of only being preoccupied with failures, in practice it appears that failures still are the centre of attention, especially in safety-critical organisations. We reviewed literature from various scientific fields to determine what factors might contribute to this phenomenon and what needs to be considered when attempting to promote learning from success. This also helps to identify what kinds of methods are required or could be useful in success-oriented learning.

Based on our literature review we have recognized that deliberate learning from successes may be desirable at least in the following situations:

1) Systems that "never fail"
2) Systems that are complex
3) High cost of failures
4) Uncertainty of the causes behind success

The first situation occurs particularly noticeably in so-called "ultra-safe" systems (Amalberti, 2006), such as nuclear power plants. These systems appear to be extremely stable and failures take place so rarely that opportunities for learning become scarce (Andriessen & Fahlbruch, 2004, p. 148; Hollnagel, 2013), which also means that there is a lack of information sources if only failures trigger learning. The second situation refers to systems that behave in a complex manner – they are inherently unpredictable and continuously changing. Such characteristics may render failure-oriented interventions obsolete and less efficient (Dekker et al., 2011; Hollnagel, 2013). The third situation describes systems where the cost of errors is so high that conventional methods of learning such as trial-and-error, intentional creation of variance or experimentation is not acceptable (Ellis & Davidi, 2005). Finally, the fourth situation describes the condition where the learning agents are unsure of what underlying factors have contributed to the successful performance and wish to avoid faulty attributions (Ellis & Davidi, 2005).

Maintenance activities at nuclear power plants have the potential to relate to all of the abovementioned situations: Nuclear power plants are very robust and reliable systems and thus failure-related learning opportunities are somewhat rare; on the other hand, nuclear power plants are also massively complex socio-technical systems (see e.g. Perrow, 1984; Reiman, 2007; Vicente, 1999), which involve the cooperation of a variety of interconnected social and technological elements; in addition, nuclear power plants have the potential for major catastrophes, and any failure is suspect to extensive scrutiny from various political and regulatory bodies – failures are therefore highly unacceptable; finally, maintenance staff may experience uncertainty regarding real causes behind the successful performance due to the intricacies of the work arrangements involving e.g. third-parties or organisational networks, potentially unavailable or delayed feedback regarding work outcomes or overall complexity of the system which may make it difficult to ascertain the exact cause-effect chains that led to the successful outcome.

Mature organisations, especially in safety-critical domains, have typically established formal and systematic failure-oriented methods of learning. This raises the question of how to transform the system and the staff so that they would also learn from successes: is learning from successes essentially an identical process to learning from failures or does it require any special considerations? We propose that learning from successes and learning from failures appear to differ from each other at least in the following ways: The way in which the learning process is commonly triggered, what is typically the nature of the learning process, and what is the outcome of the learning process. In addition there are indications of nuclear industry-specific factors that may affect how learning from successes can be promoted. These common differences lead to some potential pitfalls and remedies for them that are specific to learning from successes.

2.4.1 Salience and negativity bias

Ellis and Davidi (2005) propose that learning from failures is usually initiated by a negative divergence between either explicitly expected outcome or internal mental model of the outcome, and the experienced outcome. Learning from successes, on the other hand, would be initiated by the conformance between expected and experienced (Ellis & Davidi, 2005), or by a positive divergence. Furthermore, motivational aspects such as the striking and urgent nature of failures may affect how the learning process is triggered (Ellis & Davidi, 2005). In this subchapter we will focus on two basic phenomena that can be considered especially relevant when it comes to promoting learning from success: salience of the event and negativity bias.

It is a well-documented psychological tendency that disruptions attract more attention and interest than routine and expected states. This tendency is often called "salience" – the ability of something to stand out and attract attention. Assuming that such tendency also applies to any task-oriented activity such as operations in nuclear power plant, it's possible to make a deduction that maintenance events that are in some aspect salient, attract attention: For example, tasks or task outcomes that are unique, rare or otherwise outside of the expectation boundaries. Conversely, this suggests that "normal" activities with expected processes and outcomes are less salient and thus are likely to receive less attention. Furthermore, as discussed in chapters 2.2.2 and 2.2.6, the expectations might not be completely objective or uniform; this may suggest that not just the objective properties affect the salience but also how the outcome is perceived or constructed. It has also been suggested that it is the rarity of the event that mostly affects the learning process rather than whether it has been success or failure as such (Garzon-Vico, 2012), which further emphasizes the relevance of salience. Based on this notion, Garzon-Vico (2012) speculates that in a success-dominant industries, learning from failures would provide more learning benefits. This is relevant to many mature safety-critical organisations such as the nuclear industry, which tends to succeed in their activities. Weick and Sutcliffe (2007) use the concept of "dynamic non-event" to describe the nature of safe and reliable performance. This concept highlights that a system which is in a state of safety and reliability is rather non-eventful: "*there are constant outcomes and nothing to watch*" (Weick & Sutcliffe, 2007, p. 40). Paradoxically, however, the system constantly puts a lot of effort, for example, through continuous adjustment and compensation, to maintain that safety and reliability (Weick & Sutcliffe, 2007). This suggests that the safety itself is not a very salient thing and therefore important lessons may be missed.

In nuclear context similar effect was observed in a study about maintenance work practices during outages: informal practices that contributed positively to the task and were casually applied by the workers were perceived so mundane that they didn't pay any attention to then and considered the work task as uneventful (Gotcheva et al., 2013). This suggests that the positive contributions applied by the workers might never be intentionally discussed or shared because no-one pays attention to them. This is further illustrated in a study about the use of human performance tools in nuclear industry where it was discovered that shop-floor workers find it needless to discuss successful tasks afterwards in post-job reviews: "*if a task is solved as planned there's really isn't much to talk about*" (Skjerve & Axelsson, 2014, p. 68). It was considered more useful to discuss the task in a post-job review if something had not gone as planned – and since most of the time everything in nuclear maintenance everything goes as planned, post-job reviews weren't perceived to be required very often (Oedewald et al., 2014). As mentioned previously, this may paradoxically lead to a situation where the learning opportunities of the organisation become scarce.

In addition to the previously discussed idea of salience, it has been suggested that individuals also exhibit a trait of negativity (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001; Rozin & Royzman, 2001) – this effect is conveniently coined "negativity bias". Negativity bias is a universal trait in humans that puts more significance on negative events (Rozin & Royzman, 2001). Some of the ways in which negativity bias can be manifested is that negative events are more potent and salient than positive events, or that negative entities are often much more elaborately construed than positive ones (Rozin & Royzman, 2001). In empirical studies the effects of negativity bias have been observed in both attention (e.g. negative events are better and more quickly identified and the search for negative entities is more efficient) and learning (e.g. negative events produce learning that is faster and more resistant to extinction), as reviewed by Rozin and Royzman (2001). An example of negativity bias that relates specifically to learning was observed by Zakay, Ellis and Shevalsky (2004). In their study, Zakay et al. (2004) first asked managers from various domains to review descriptions of decisions and their outcomes – which contained both negative and positive outcomes – and then asked the managers to evaluate to what extent learning would be needed in each situation. The results demonstrated negativity bias: the more negative the outcomes were, the more likely the managers were to recommend learning activities; furthermore, the managers were found to be more likely to recommend not doing anything after positive outcomes

(Zakay et al., 2004). In the context of accident investigations, Dekker (2002) speaks of "window of opportunity" that is temporarily opened by failures such as accidents or events. During this temporal window, the organisation is more willing for self-examination and open for change, levels of hierarchy within the organisation are blurred leading to joint effort, and extra resources may become available (Dekker, 2002). This emphasizes failure as a driving force for organisational development. Similarly, Madsen and Desai (2010) concluded in their empirical study of learning in orbital launch industry that failures appeared to contribute more to learning than successes, and that the lessons learned from failures was more persistent (see also chapter 2.4.2). Altogether this seems to make it more likely that organisational learning and changes are initiated by failures rather than successes.

There also appears to be some indications of "institutionalized" negativity bias in the nuclear industry – i.e. the industry standard practices and its authoritative entities such as regulators affect the learning processes by promoting attention towards negative events. One such example is the commonplace policy and requirement that incidents, events and other forms of non-conformances of sufficient significance are required to be analysed, reported and corrective actions planned – however there doesn't seem to be explicit requirements for analysing significant successes in the organisation. For example, Finnish regulation regarding operating experience activities (STUK, 2014b) focuses quite clearly on operational event (i.e. failures, flaws) analysis and reporting. Promoting failure-oriented approaches to learning may affect how organisational culture of the nuclear plants is formed: analysis or discussion of successes may appear alien and might not even be considered feasible. There are, however, notable exceptions to this. For example, IAEA operating experience guidelines mention using good practices or positive things as sources for learning or providing noteworthy examples (IAEA, 2008a); likewise, WANO collects and provides good practices for power plants based on what has been proven effective as a part of their technical support and exchange programme (WANO, 2015).

The findings about the salience and negativity bias effects in both individuals and organisations suggest that it can be counter-intuitive to intentionally begin learning from successes – especially if the successes have been "normal" activity rather than extraordinary achievements. Organisational and individual learning appears to be more likely to be initiated by negative and disruptive events. This suggests that the following three conditions need to be met in order to initiate conscious learning from successes:

1) The successes need to be made salient
2) The possible negativity bias needs to be considered
3) There needs to be a starting point that would help analyzing the successes

However, it also needs to be acknowledged that, quoting Zakay et al. (2004, p. 156), "*starting a learning process after negative outcomes reflects good management*". Similarly, Weick et al. (2008) argue that one of the essential characteristics to good safety management is the preoccupation with failures. This is also reflected in an empirical study that assessed learning results after various outcome situations using learning from success, learning from failure and a combination of the two approaches for learning: it was observed that after successful events, approaches that emphasized learning from success produced less optimal learning results than those that emphasized failures – this may mean that discussing successes may actually be harmful for the learners in some situations (Ellis, Mendel, & Nir, 2006). This suggests that when attempting to create the capacity or preconditions for learning from success, *one mustn't obstruct the opportunities to learn from failures or create a motivational void for learning – a* *safety-critical organisation mustn't become preoccupied with successes or be complacent with its activities*.

2.4.2 Learning process considerations

There are indications in the literature that unlike failures that are more likely to initiate active and systematic learning processes, successes usually trigger spontaneous learning or routinisation. Andriessen and Fahlbruch (2004, pp. 9–10) summarize that learning from failures often assumes a formalised approach, initiates systematic analyses, creates codified reports and involves institutionalization – conversely, learning from successes is more reliant on less formal and systematic methods and less institutionalisation is involved. There is some evidence of this distinction in empirical studies, namely in the form of how information is preserved in the organisation. For example, higher probability of persistence of lessons learned from failures rather than successes has been observed. In their empirical study of orbital launch industry, Madsen and Desai (2010) found that knowledge learned from failures is more likely depreciate slower than that which is learned from success. They suggest that this is because knowledge learned from failures is more likely to be codified in organisational structures or other stable systems (Madsen & Desai, 2010). This finding can easily be connected to nuclear industry: major failures cause licensees and regulators to revise their practices, introduce new instructions, rules or even legislations. Better retaining of learned information have also been observed in individual level in the context of training (Joung, Hesketh, & Neal, 2006). Respectively, success-related knowledge may be more vulnerable phenomena such as personnel turnover or organisational changes (Madsen & Desai, 2010) during which the structures that hold non-codified information (e.g. individuals, informal groups, tacit knowledge) are threatened. It is, however, possible that also lessons learned from successes are stored in stable structures: for example, best practices or other formalised practices of the organisation may be generated from successes.

2.4.3 Reinforce or challenge status quo?

Learning from success or failures may also have an effect on what is the outcome of the learning process; or more specifically: what is done with the information gained from the outcome. Commonly it is thought that successful outcomes tend to promote satisficing, or reinforce or refine the associated routines; conversely, failures are believed lead to a search for alternative practices (Levitt & March, 1988; Muehlfeld, Rao Sahib, & Van Witteloostuijn, 2012).

In the context of developing the adaptive performance of firefighters, Joung et al. (2006) compared two approaches to training, errorless (i.e. involves trainee exposition to successful scenarios where no major problems occurred) and error exposure (i.e. scenarios contained errors that led to significant damages), to establish which one is more beneficial for enhancing adaptive performance. It was noticed that those who participated in errorless training were typically less able to identify problems, come up with new approaches or review existing strategies (Joung et al., 2006). This suggests that success-oriented learning, in addition to reinforcing the use of existing practices, may have the potential to promote rigidness and hinder development. Similar effect has also been identified on organisational level: companies that have experienced extensive past success are more likely to become strategically persistent (e.g. uninterested in revising or assessing the validity of prevailing practices), which eventually has led to their decline (Audia, Locke, & Smith, 2000). Weick et al. (2008) also warn that preoccupation with successes may lead to "mindless" behaviour that encourages simplification, routinization and blind compliance – essentially as a result of reinforcement of and overreliance on existing practices.

Another property of outcomes that may affect the learning process is the amount of usable information that is available from the event. Muehlfeld, Rao Sahib and Van Witteloostuijn (2012) point out that failures contain richer cues regarding causality because they create new and unexpected types of information. This may mean that failures provide a more approachable starting point for analysis and thus learning. For example, an incident such as breakdown of a machine usually provides clear and salient starting point for further investigation: What happened? What was the immediate cause? What were the contributing factors? A successful, especially if normal, activity might not easily provide any of this information – everything went as expected. Ellis and Davidi (2005) propose that in success situations, the learners should put special emphasis on analysing their mental models and decision-making logic: by systematically reviewing their actions after the task in after-event-review meetings, learning from successful events might be enabled. In a similar vein, Gino and Pisano (2011) note that organisations commonly disregard successes and propose that an organisation should consciously initiate reviews or investigations of success: applying similar level of scrutiny to successful situation as to a failed situation to find the causes that led to the success. They argue that even those processes that appear to be working correctly require critical "theory testing" to ensure future success (Gino & Pisano, 2011).

Rosness, Theraldsen, Tinmannsvik and Wiig (2014) discuss the connection between organisational learning to safety by making a case of how spontaneous learning (e.g. non-codified, tacit and intuitive methods) and managed learning (e.g. codified, active methods, institutionalisation) relate to safety. They suggest that organisational learning may cause an unwanted phenomena of drifting into failure, both from spontaneous (e.g. practical drift) and managed learning activities (e.g. normalisation of deviance) (Rosness, Theraldsen, et al., 2014). This drift takes place through continued successful adaptations through which the system may evolve towards either further successful adaptations or increased brittleness (Rosness, Theraldsen, et al., 2014). Rosness, Theraldsen, Tinmannsvik and Wiig (2014) argue that one of the ways the issue of maladapted deviations could be rectified is by facilitating explicit discussions about what kind of activity is desirable and accepted. This notion is in line with the previous findings which suggested explicit examinations of successful activities.

In conclusion, it appears that previous successes are more likely to lead to reinforcement and possibly even to a lack of adaptive capacity, while failures are more likely to lead to challenging the existing practices. This has some important implications regarding the promotion of learning from successes. Learning from successes shouldn't be considered as a target in itself but rather as a mean to achieve future success: learning from successes should result in more successes instead of failures. Conscious and informed scrutiny may be required – at least every now and then – to make sure that unwanted lessons are not reinforced through past successes. Conscious scrutiny also allows more attention to be put on analysis of successes. Therefore, *when attempting to generalize or implement a lesson learned from a successful event, it is important to carry out a proper examination of the lesson to avoid any unwanted consequences*.

2.4.4 *Summary*

Based on the literature reviewed in this chapter it appears that learning from success and learning from failure may be distinct processes that differ from each other at least in the following terms:

- *Triggering*: successes attract less attention than failures and thus are not as likely to initiate intentional learning processes
- *Motivation*: successes are less likely to motivate spending much effort on learning, failures initiate extensive organization-wide changes
- *Storage*: lessons learned from successes tend rely on less formal processes, failures are often stored in stable organizational structures
- *Effect on existing knowledge*: successes tend to reinforce existing knowledge, failures challenge it

In order to promote intentional learning from successes, techniques such as making the successes more salient and "exciting" or enforcing the scrutiny of successful operations may be needed. It is also important to consider that learning from successes shouldn't be a goal in itself, but rather the subsequent successes that stem from the understanding processes better. The potential negative side-effects that arise from focusing on successes need to be addressed and avoided. Figure 5 illustrates the inherent tension between learning from successes and learning from failures: both are required for future successes but both also have the potential for causing future failures.

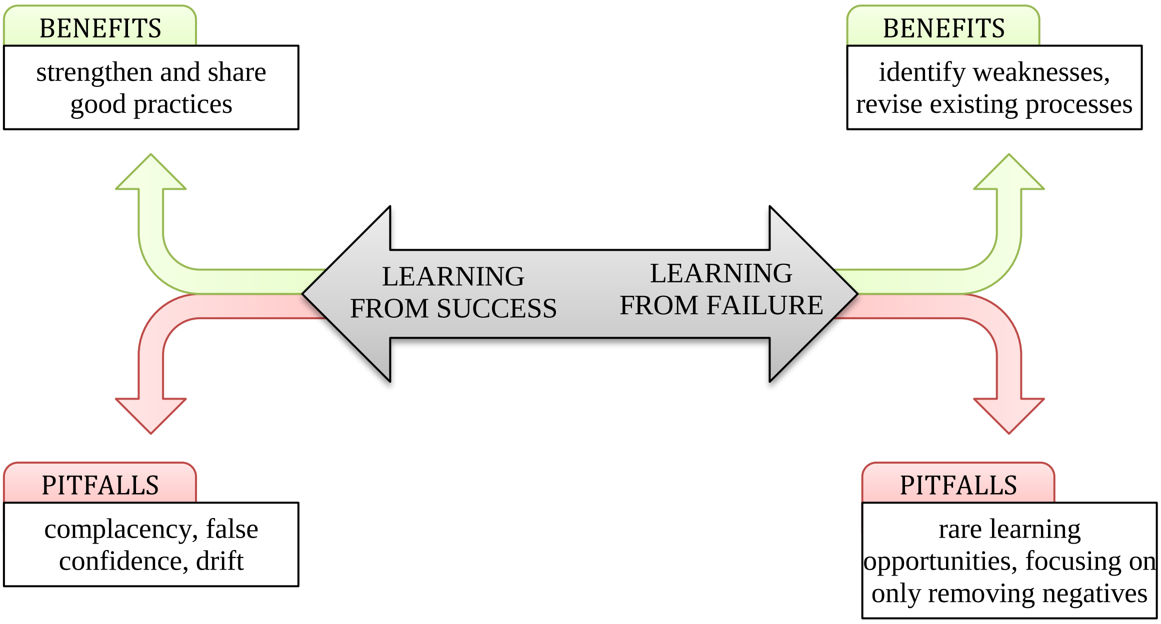

Figure 5. Benefits and pitfalls of learning from successes and learning from failures

3 Empirical study at plant A

We carried out an exploratory case study at a nuclear power plant. The case study aimed to produce practical insights from plant A as a complement to our theoretic work and empirical work at the plant B case study. The approach used in this case study stems from our theoretical work and is loosely similar to that used in plant B.

3.1 Data collection

Case study at plant A was mainly focused on shop-floor maintenance activities, especially complex lifting tasks; however, there were also cases that involved planners, operator personnel or IT staff. The case study at plant A had three approaches to data collection:

1) General part of the interviews
2) Document analysis of event reports with follow-up interviews
3) Field observations with follow-up interviews

A total of 8 interviews were conducted. The interviews were semi-structured and were based on the interview scheme created for the purpose of this study (see Appendix 1). The general part of the interviews involved discussing how the interviewee understands the concepts of success and learning in his/her work context, and also other orienting questions. The rest of the interview dealt with the experiences and conceptions related to some specific event (described in an event report) or field event (observed by researchers), depending on what the interviewee has participated in. In the interviews, two researchers were present, one focusing on leading the interview and the other making complementary questions when needed.

The other two approaches, event report analysis and field observation, were chosen due to the complementary nature of them: event reports provide a failure-oriented approach and field observations typically a success-oriented approach. This duality of approaches also allowed a more diverse variety of data to be collected from different contexts. In addition, using these data collection methods provides us an approximation of what kind of data operating experience personnel commonly collects and analyses.

In order to carry out the document analysis of the event reports we requested a variety of event reports from operating experience group of plant A. The cases were recent reports chosen by a contact person at plant A. The reports covered a variety of situations of minor safety-significance, including some that were related to heavy lifts. The reports followed the company standard form and their length ranged between 1 and 9 pages. The reports included, among other things, a description of the event and its precursors, and a description of corrective actions. After having reviewed the reports we chose six reports we considered particularly interesting from the study’s viewpoint and conducted interviews with some of the personnel that were either involved in the reported situations or knew the context well.

The field observations in plant A were carried out during an outage. We focused especially on two complex lifting tasks (one in reactor hall, another in turbine hall), but smaller tasks and general activities at the plant were also observed. A total of three researchers participated in the field observations. During almost all of the task observations, two researchers were present to ensure sufficient diversity and reliability of the data collection. This overlap also allowed us to better reflect and further discuss our observations. As a follow-up to the field observations, we carried out two interviews with staff that was involved in the two lifting tasks we observed.

3.2 General part of the interviews

Analysis methods

The general part of the interviews involved first a brief discussion about the interviewees' background and experiences in their current work position. The interviewees were then asked how they understood the concept of success and learning in work context. The interviews were audio recorded and transcribed for later analysis. An analysis of the general part of the interview was conducted by identifying and collecting interviewees' comments under the three main predefined themes/categories: challenges in work, perception of success and perception of learning. The analysis was further continued by identifying what kind of sub-categories and viewpoints could be formed under each of the main topics. The analysis was also kept open in case any totally new themes would emerge from the interview data.

3.2.1 Challenging aspects of work

First the interviewees were asked about the challenges that they face in their current work and areas of responsibilities. We assumed that understanding the challenges may give us clues regarding what are the possible reasons behind adaptations. In addition, identifying the challenges may give us hints regarding what things should be paid more attention to when trying to learn. Common to all of responses regardless of the interviewee's organizational position or status was the vast amount of factors to be taken into account and managing and scheduling all the interlinked tasks and activities. For example, one interviewee that had many employees under his supervision experienced orchestrating all the activities challenging from both human resources as well as subject area management point of views. On the other hand, another interviewee that worked at shop-floor level commented that seeing and understanding the connections of own work in relation to all the other activities is challenging. Overall, coordinating and scheduling the work was thought to be one of the biggest challenges according to the interviewees.

Another theme that was continuously raised up by the interviewees in relation to the question of challenges in work was the demand for learning new things and adapting to changes. Things such as ageing of the plant, standardization and advances in technology cause constant pressure to update and develop systems and procedures as well as the personnel skill and competences. The interviewees thought that keeping up and following these developments and changes were challenging. One interviewee described this challenge with the following example:

> *"The plant and the systems should be maintained and kept operational. Most of the systems are also such that they should be operational round the clock. Introducing new things and still reaching certain reliability and feeling of control in operation is a big challenge."*

From the skills, competence and work organization point of view the interviewees experienced challenging the fact that the "old" tasks and duties remain, but at the same time along with the plant modifications and system updates many totally new responsibilities and tasks are signed for them.

3.2.2 Perceived success criteria

The concept of success is one of the key topics in the LESUN project. In the interviews the success was also discussed extensively. The interviewees were asked:

1) How is it known that the work task has been successful?
2) Can you name any personal success criteria?

Following plans and keeping schedule
By far, the most referred form of success was when in the work or operation everything goes as planned and scheduled. One of the interviewees summarized this type of success as follows:

> *”Success is when everything goes as planned. I think it is when we can execute the plan and the work without any major and noteworthy incidents and when things are done right and as they are meant to be done.”*

Whereas another interviewee stated:

> *“If I get something done on time it is a kind of success I would say…”*

The work plan and the schedule were seen as main defining factors and criteria for success. Proceeding according to the schedule was an especially important success indicator during outage operations.

Number of events, incidents and reports
Interviewees also mentioned other specific criteria for success. For example, the amount of open work orders or event/incident and special reports can indicate the success of the operations. In such cases the less there is to repair and report the better the operations has succeeded. In addition to these official documents also some statistic information was used as indicator for success. For example, one interviewee followed radiation dose statistics:

> *“Some trends exist where you can follow how for example radiation doses have developed over the last 10 years… And the collective radiation dose has come down from the earlier years. I would say that at plant level we have succeeded.”*

Feedback
Also, feedback was identified as an important indicator for success in work. For example, direct feedback from end-users (e.g. how the use of some equipment or tool has been experienced) was considered essential background information when doing purchase decisions. One interviewee whose work included a lot of preparing and reviewing official documents considered that the feedback from the authority indicated how well he had succeeded in his work:

> *“If you have a job to prepare and write documents that should be accepted by the authority and you send one for them to be accepted and it is confirmed it is a kind of success.”*

The interviewees also reported that sometimes it is not clear if the activity has been successful or not as nobody gives feedback on it. One interviewee stated that:

> *“Normal operation is not reported anywhere. And only when something goes wrong questions are raised.”*

Recovering from disturbances

In addition to efficient workflow, effectiveness and considering safety in problem solving was seen important for success in work. The organization should be able respond to problems and operational situations in an effective and safe manner. According to the interviewees, it is about the quality of the whole problem solving process starting from observations, and then involves diagnosing the situation, constructing a plan and communicating it within the organisation, and finally carrying out and executing the corrective actions that define the successfulness of the activity. One interviewee emphasised the importance of communication in problem solving as follows:

> *“Success is when all the necessary parties are informed and involved in solving the problem.”*

Another aspect to the successfulness of the problem solving activity was the end result of it. Problem solving was seen successful when (some) system could be returned to operation with minimal time delay or when the harmful effects of (some) disturbance or system failure could be minimized by preventing it to escalating into something more serious.

> *”We can say that we succeeded well when the problem did not lead to any more serious equipment failure or long-lasting production breaks.”*

Creating something new

Somewhat similar to problem solving is the innovating and inventing new things in work that the interviewees recognized as one form of success. In general, the interviewees thought that improvements and implementing ways of easing work are also successes. The new innovations could concern ways of doing things, procedures or even tools and process systems (e.g., automating time consuming, manual, laboured tasks). One interviewee described the success in practical work development this way:

> *“Last year we had a tool that still needed some development work and it had been improved a bit and then this year we found out that actually it is quite good now and it suited well to its purpose.”*

Another interviewee thought that sharing and going through this kind of successful innovations in work could inspire and cheer people in viewing their work from new perspectives and in adopting more developmental approach:

> *“It could be interesting to sometimes go through things that, for example, made changes that have been beneficial. This is what we did and these kinds of good things followed from it. This could be beneficial in terms of inspiring people to propose and innovate new ideas.”*

Significant observations

The last distinct form of success recognized by the interviewees was noticing something of importance by coincidence or chance. One interviewee demonstrated this with an example from his personal experience:

> *“When doing their maintenance work they had noticed these hot spots there and immediately contacted us about these worrying*

observations. This then eventually led us lowering down the power and to make some necessary repair works in the system."

In this particular case making notice and connecting its meaning to a possible risk in the system started a series of events that led to a successful and appropriate management of the observed situation and thus possibly avoiding a more serious process failure. Another example of this kind of success was a case in which personnel noticed non-operability of equipment that was not directly under their supervision:

> *"I think it was by chance that it was noticed so quickly that it was not switched on. They should monitor it, but the alarm about the non-operable equipment caused by the maintenance task had already been acknowledged in the beginning of the task."*

In both of these cases the success was originating from the sensitivity of personnel and the ability of the individuals to make sense of the situation and look ahead and beyond their own area of responsibility.

<u>Subjective success criteria</u>

The interviewees were also asked to talk about their own personal criteria for success. In nuclear domain work highly regulated through variety of safety standards and procedures and the interviewees had some difficulties to express their own criteria as the objective demands set by the organization (e.g. procedures, work orders and schedules) were so strongly influencing in the background. However some criteria were mentioned in the discussions. For example, interviewees thought that the individual aspiration levels may have an effect on success criteria. This came evident in comments such as the following:

> *"Of course everyone sets their own level of quality that they want to reach in their work."*

Or:

> *"If you think this from the point of view of professional pride… You do things and your job well and you get yourself a feeling of success, even if you would not get any feedback or extra payment from anyone."*

Some interviewees brought up that positive attitude may influence how tasks are perceived:

> *"When you can start thinking small everyday things such as: this meeting went well or that during the outage we managed particularly well in this [task]… Even small things like that can be uplifting if one's attitude is right."*

According to the interviewees, the feeling of success could be reached in day-to-day operations if one just starts to be more sensitive about it. The feeling of success may also appear when you have been helpful and useful:

> *"Every now and then I help out in these [work tasks] – hold a pre-job briefing or do other things. […] You get a feeling that you have done something useful. Useful and concrete."*

Or you are able to finish some task:

> *"When I finish some task, it produces me the feeling of satisfaction."*

<u>Conflicted success</u>
It is often said that there are as many opinions as there are people involved. In a big organization like a power plant it is important that people are working for a common goal and do cooperation organization wide. The interviewees were asked if there are any disagreements regarding success at work tasks. A variety of examples of conflicted successes were recognized by the interviewees. For example, when many different groups are working in the same project:

> *"It is possible that when multiple tasks are interrelated, I succeed in my own task but the other party does not or vice versa."*

Another example on conflicted success was found in a situation when the involved parties perceived the success in the task at hand differently. One interviewee described a situation where he had been involved in repairing a system. After getting the system operational the other involved party had been satisfied and though that the quick repair and handling of the problem had been success whereas the interviewee thought that the actual root cause of the problem was still remaining unresolved and thus no success had been achieved (see more detailed description in case 3).

The interviewees also thought that it is not enough that an individual succeeds in his/her task if the overall quality of performance in the group or plant is not at the satisfactory level:

> *"Good practices of single individuals do not still actually mean anything in the whole."*

On that account the interviewees thought that sharing and communicating also the positive insights of work would be beneficial for developing the profession and the ways of doing things.

3.2.3 Means of learning and sharing information

Learning was another main topic in the LESUN interviews and in particularly learning from success. In the interviews two main questions concerning the concept of learning were discussed:

1) What are the most important ways to learn when at work?
2) Are successful experiences discussed and shared for learning purposes?

The interviewees reported a rich set of ways to learn in work. All of them agreed that learning is a continuous process and something that requires both individual commitment as well as organization that promotes and supports building and maintaining know-how. The first distinct way of learning can be grouped under the theme of "formal training". This included all official trainings and educational seminars being provided by either the internal instance or some external partner. One interviewee mentioned simulator training as especially important way of learning for operational staff:

"For the training and learning of operational staff this [simulator] is very essential environment: we get to train and do things that have never happened in real life or are very rare and in that way prepare ourselves to handle those situations."

The interviewees mentioned factory and acceptance tests as particularly good means to learn new things and gain experience for future use:

"Usually when in some project we introduce and take some new system or tool into use there are factory tests organized at the system provider's… vendor's site… we participate in those and those are the best occasions to learn…"

But learning at work can happen also in more unstructured and unofficial ways. Problem solving in everyday practical work situations was seen as an effective way of gaining new insights:

"Usually when you start solving some problems or issues you also learn new things at the same time. It is little bit like at the university: you might sit at the lecture and listen, but when you actually start doing the assignments by yourself you learn the most."

According to the interviewees, the background information for problem solving is readily available in literature and different documents connected to the field (e.g. procedures, standards, manuals, system providers' and vendors' documentations).

On the job learning was recognized as one of the most important way to develop professional skills and competences. In this context, the main learnings are derived from everyday work experiences. The interviewees stated:

"When you do different kind of work tasks and assignments that come ahead over the years, you learn from those."

In the same vein the colleagues' work experiences were also recognized as a valuable source of lessons. One interviewee noted that:

"Certain persons know certain systems, tools and methods or parts of the process better than you and you can always ask help from them."

<u>Learning from success</u>
The idea of learning from success was not considered totally unfamiliar by the interviewees and many variants of learning from success were recognized. Maybe the most informal one was seeing the positive effect of own efforts that induced individual's learning process. The same can then be extended to sharing the positive observations with others. Giving or getting positive feedback about the observed good practices and realized improvements was experienced important:

"When good attitudes or new ways of doing things are observed that are clearly good and positive for the development of the whole system

> *or working practices, and you get feedback from it, this promotes learning."*

One interviewee told how he had been positively surprised in a pre-job briefing the other day:

> *"Our new supervisor held a very good pre-job briefing a few days ago and I thought that I really need to mention about this to him as a positive feedback. Taking this kind of thing on discussion is important in my opinion."*

One degree more formal learning from success is realized in official post-job reviews and review seminars where the recent work tasks, incident and event reports are discussed. Even though the focus in these meetings is usually on learning from mistakes, the interviewees told that also positive things are increasingly being raised. Updating training and simulator training were seen also good sources of learning from success. One interviewee explained that:

> *"You learn something that could be done better… But you can also experience feelings of success when you realize that actually we made it and we can handle this situation, even if it is just a training scenario."*

Casual discussions with colleagues were also considered important. According to one interviewee:

> *"It does not need to be an organized group discussion. We, for example, have a small group in the office where we change ideas during pauses from other work. This is important. Of course, we then also exchange information with emails and through other channels."*

In the end, the most important according to the interviewees was that the success and the recognized good practices were someway shared within the whole organization. However, some interviewees were a bit sceptical if the lessons learned can be disseminated in any other way than by proceduralizing them or embedding them in other official instructions and documents:

> *"When some good working practices are formed in some group, we try to integrate the practices into our procedures, because they are good practices. If they are acquired just by one or two persons, it does not develop this too much. We should take them into use organization wide."*

3.3 Event reports

Analysis methods

The document analysis of the event reports was started by identifying the successes in the described situations based on the theoretical insights of what can be considered success. We also attempted to identify potential indications of adaptive performance. After this, we conducted a follow-up interview in which the case was discussed in more detail. In the interviews we focused on the positive performances in the situation and tried to identify the contributing factors that led to them. The subsequent data analysis involved extracting successes, potential adaptive behaviours and lessons learned from the interviewee's responses. We also compared the interviewee's comments to our own reflections before the interview to validate whether it is possible for an individual to identify a valid starting point for learning from success based on report data only.

Case 1: Handling objects in a temporary storage with new means

Case description

The report describes a chain of events related to the temporary storing of radioactive objects and the lifting of these objects afterwards. This task included problem solving because the usual device for storing the objects was not available and new means had to be discovered rapidly. The storing was successful; the objects were located in safe place where they did not cause harm, and the lifting of the objects was performed later based on a separate work order. The interviewee wasn't directly involved in the event, but knew the context and this particular case well.

Successes and adaptations

Based on our initial analysis of the event report, we found that inventing something was the main successful aspect of this task. In a detailed level, the researchers identified several successes:

1) The objects were located to a place where they did not cause harm.
2) The personnel decided to broaden its view by becoming more aware in the future of the problems related to handling various materials when radiation is to be taken into account. This is reflected in the decision to investigate the appropriateness of tools used in this context, a matter not discussed before this event.
3) The options available for storing radioactive objects was expanded for the future as it was decided to plan and provide new containers suitable for temporary storing; the new containers are not only suitable for wet storing but the same containers can be transferred as such to the dry storing location.
4) Storing the object to the new container will be easier than currently as a new device will be produced.

According to the interviewee, because the objects were relatively long in the wet storage, it was successful that finally a means was found to lift them away from there. That was due to the finding of correct contact persons. Thus, interviewee stated there were two interconnected successes: one represented by lifting the objects as originally intended, although later than perhaps first expected, and another represented by the way the lifting was enabled. Knowing the right people was emphasised in the work of the interviewee in general, so that may be one reason why the interviewee pointed out this matter.

In the interview, the detailed successes identified by researchers (described in the list above) were not scrutinised but as a whole, the interviewee mentioned that a lot of good consequences followed this inoffensive incident:

> *"That was, say, a harmless misfortune, which was followed by a lot of good things."*

To conclude, interviewee's opinion and researcher's reflections met in a general level.

Lessons learned

According to the interviewee, the knowledge of whom to contact when there is a need to lift something from the wet storage was the one success which the interviewee can concretely use also later in similar types of situations. The invention of new devices to handle this type of situations is a more broad indication of lessons learned, important and valuable for work for all personnel doing these tasks.

Overview

It was not immediately easy to find success from the event as so much seemed to go wrong. However, some success was found within the event itself and specifically from the planned activities afterwards. It was decided not only to correct what was made incorrectly or in a deficient manner but new inventions were made to broadly facilitate similar types of situations in the future. Also the interviewee identified this success, although not in such a detailed manner than the researcher did.

The interviewee also found one success which could have been found from the report but which wasn't initially found by the researchers, that is, the success of lifting the objects as was planned, even if it took more time than expected. Additionally, the interviewee also had more information about the case than was reported due to which the interviewee could label the finding of correct contacts eventually as a reason for the success of finally lifting the objects – in the report, the duration of the storing of the object in the wet storage was not defined, nor that it was not evident how to proceed when it is time to lift the objects up. On the other hand, mentioning of the importance of finding the correct people to do the task does not appear relevant in these types of reports. It represents tacit knowledge, something that easily appears as self-evident, even if it is not.

Even if the interviewee was specifically asked to name successes, also a failure (work is not done) was mentioned as something about which to learn (it is important to follow work orders). This reflects the difficulty in identifying successes as a source for learning. Even if the interviewee defined success in the interview as something which happens when everything goes as expected, it does not seem to alert the same way as failure does, even if proceeding as planned may raise satisfaction.

Case 2: Containing a water leakage in turbine hall

Case description

The report describes an event during which non-radioactive water leaked into the turbine hall. Leakage management and cleaning operation were initiated swiftly to avoid damage to machinery near the leakage. No major damage was caused by the leak. Our interviewee wasn't directly involved with the situation, however he was present when the situation took place and inspected the site.

Successes and adaptations

We interpret this as a "recovery success" because the system was initially in an adverse state due to the leak but after the containment activities, the functionality returned to normal. Even though this is not directly related to turbine hall itself, due to the implementation of the subsequent corrective actions, the system can also be considered as having returned to a better state than before. When asked about successes, the interviewee identified two main types of successes in this event:

- Reaction of the organization was quick

- Outcome could have been worse

These two types of successes appear to be bi-directionally interrelated: the reaction was quick due to the proximity of machinery, and the worse outcome (i.e. damage to the machinery) was possibly avoided due to the quick reaction. It seems that the main goal in the situation was the protection of the machinery from water. This goal was also achieved because the machinery didn't suffer significant damage; however, there were indications of "conflicted success": due to attempting to contain the leak swiftly, some work process-related aspects, such as organizing a pre-job briefing, were skipped, which caused a potential occupational safety hazard. This suggests a conflict between different types of safety.

Based on our initial reflections after reading the event report we identified three successful aspects of the event that may have contributed to the successful recovery which we discussed in the interview:

1) Noticing the leak
2) Deciding what action to take and organizing leak containment activities
3) Carrying out the leak containment

The interviewee didn't know exactly how the leakage was noticed – the leakage could have been noticed either by measurement devices or by visual sighting. He speculated that the leakage was obvious enough to be noticed locally at site. This suggests that there probably was no major adaptive behavior involved in the notification phase; perhaps remaining functional at a surprising situation in order to report the problem might have been a potentially adaptive performance (i.e. the "tolerant" aspect of adaptive performance as discussed in chapter 2.1.1), however, because the interviewee didn't know the details of the situation, we have no clear evidence of this. In this sense, neither this interviewee nor the event report gave sufficient information about specifics of the detection processes.

The shift manager, after having learned of the leak, decided to quickly begin organizing the leakage containment activities. There were, however, no specific procedures regarding how to proceed in this particular situation. This might suggest that a performance adaptation that allowed the person to organise the operation took place, however, when we asked whether it was due to the individual excellence of the person in charge that the activities were started swiftly, the interviewee thought that in these types of situations it is quite well-understood what to do and who to call: the organisation has a well-established readiness to respond. This may mean that even though there might not have been specific procedures for the situation, the capability to respond emerged from general know-how of the people qualified for the job. The interviewee also mentioned various simulator training exercises that are done to handle such situations. We also attempted to find out whether creative solutions or problem-solving were required, the interviewee didn't find that the recovery required any: for example, dealing with various water spills has been experienced before and they have provided experience in dealing with similar situations. All in all, these findings suggest that general training in combination with experience-based knowledge buildup within the personnel might have been the main contributors to the success of organizing the containment activity. Similarly, the actual containment activity was considered effective by the interviewee: the fire department has a very short response time and has a well-established readiness and equipment for handling these types of situations.

Lessons learned
The most apparent lesson learned from the case according to the interviewee was the implementation of the new procedure for this type of tasks. The interviewee found that the main contribution of the procedures is to improve the work process in these kinds of situations: for example, avoiding starting a similar task without proper pre-job briefing and preparation. The interviewee implied that the main lesson in this case stems from the failed aspects of the task.

Overview
In this case it was quite straightforward for the researchers to find the basic successes. Similar successes were also recognized by the interviewee. In this sense, this report gave us a valid starting point for starting the inquiry. It was, however, quite difficult to reliably identify the contributors to the success based on this data only – other than personnel experience and preparedness for emergency situations we didn't find strong evidence of the success contributors, which suggests that deeper scrutiny would be required. Similarly, adaptive behavior was difficult to capture in a robust manner, either from the document analysis of the report or from the interview – there were some indications of possibly adaptive performance, but no definitive evidence nor obvious contributors for the adaptive behavior. It is likely that due to the complexity of the event and because multiple people and departments were involved, a clear picture of the adaptive behavioral patterns is not attainable from a short report and a single interview.

Case 3: Repairing a malfunctioning server system

Case description
The report describes a software issue in a server system that caused a simple hardware malfunction to be manifested in a confusing and unprecedented way. The in-house IT specialists identified the problem and successfully eradicated the problem. Furthermore they initiated a deeper scrutiny on the malfunction which resulted in software fixes done by the manufacturer of the server system. We interviewed one of the IT specialists that were involved with the situation.

Successes and adaptations
After having reviewed the event report, we interpreted this situation as mainly a "recovery success": the server system was offline during its malfunction and therefore didn't achieve its expected performance levels. After the repairs, the system went back online. The interviewee pointed out that there were actually two types of successes during the process:

- A quick workaround that allowed the functionality of the server system to be restored
- Requesting and receiving a software fix from the manufacturer

The former type of success involved diagnosing the situation and managing to bring the system back online. The person we interviewed wasn't initially involved with the repairs; however, due to his expertise with this particular system, he was called in for help. This suggests that one of the success factors could have been a manifestation of a type of social capital: co-workers know what others know and are therefore able to optimize their behaviour. In this case, the IT specialist that was initially involved with the task knew who to call (i.e. the IT specialist we interviewed). The interviewee had previously been participating in an upgrade project on this system – therefore the system was very familiar to him. When he arrived at the work site, he could immediately recognize how to recover from the situation just by looking at the status displays: this allowed bringing the system quickly back online.

This event emphasizes the relevance of "knowing who knows": being able to recognize the experts in special areas can be seen an important success factor. When we later asked the interviewee about what factors he considers as supporting problem solving, he mentioned contacting the right persons:

> *"First of all, knowing the person who is the best for the job. Try to contact him. Such a person possesses years of experience – something that you won't find in documents."*

The latter type of success, requesting a software fix, refers to removing the underlying, or "latent" problem within the server software that caused the system going offline. This underlying problem caused a simple hardware problem to manifest itself in an unprecedented and perhaps non-intuitive way; this is why it wasn't recognized at the time of initial recovery, but only after further scrutiny. In this sense the recovery can be seen to have required adaptive performance such as creative problem-solving to identify the cause for the issue.

When we asked about possible divergences in the perception of successes during the general part of the interview, the interviewee spontaneously brought up this case as an example:

> *"They [end users] thought it was a success because the system was back online. But from our point of view, it wasn't really a success because we didn't have a solution to the problem – it might as well happen again the next day."*

This notion illustrates how the viewpoint of each stakeholder affects the perception of success. In this case, the end users of the server system required an immediate fix and were essentially satisfied with the fact that the system was functional again – from their perspective, the system provided the service they require of it. However, as the IT department better understood how this success was achieved – similar to the concept of "process success" as discussed in chapter 2.2.3 – they found that the success was not sustainable because the underlying problem wasn't yet fixed. As a result the IT department demanded a fix from the manufacturer. In addition to the stakeholder viewpoints, this particular case also highlights the temporal and systemic aspects of success. Getting the service back online was considered an important priority, therefore there clearly was an immediate, short-term goal, which defines one aspect of success; another was more system-wide, but not immediately achievable long-term goal of removing the undesirable software behaviour from the server system. Achieving both of these goals was required for retaining the functionality of the service.

In addition to the abovementioned two types of success, the interviewee also mentioned subjective experience of success. At the time the event took place, the interviewee was off-duty and on vacation; when the problem had to be quickly fixed, he was called to help out because of his specific expertise.

> *"There was a certain feeling of success when my colleague was already there and I came and could help him solve the problem."*

This comment by the interviewee brings out the aspect of positive affect caused by success experiences, which is not discussed in the theoretical part of this report. This area may be of interest when promoting learning from successes, and during the next year's activities in this project.

Lessons learned

When we asked of the lessons learned from this event, the interviewee thought that the most important lesson was that the situation made it possible to understand the system even better: this particular behaviour of the software wasn't known to the interviewee before. Our interpretation is that this lesson on one hand stems from the failure of the system which had made the problem salient, but also from the successful identification process that was initiated by the IT specialists. On a more general level, the interviewee also referred to a certain type of knowledge redundancy in their organisation as a positive contributor to solving problems: because problems can emerge anywhere, as the experience cumulates, understanding of other than your "own" systems is also improved. In this case, perhaps the main learning beneficiary would be the interviewee's co-worker that wasn't especially familiar with the system but who participated in solving the problem.

Overview

This case illustrates some of the aspects to success recognized in the theoretical part of this chapter, such as the viewpoint differences due to multiplicity of stakeholders and the temporality of success (i.e. long-term and short-term goals). The case also illustrates how the apparently informal social aspects in the organisation may contribute to successful outcomes. From adaptive performance point of view, it was recognized that a technically complex, problem-solving oriented and sometimes insufficiently documented environment in which the IT department operates, may provide interesting insights to recognizing adaptive performance. Many of these insights were absent from the report and were discovered during the interview.

Case 4: Restarting an inadvertently offline measurement device

Case description

After a simple, routine maintenance task, a measurement device was forgotten to put back online due to an interruption during task execution. A worker that didn't participate in this task but was working with measurements, noticed that this measurement device was offline. As a result the measurement device was turned back on. Our interviewee didn't directly participate in the task but has an overall responsibility, among other things, for these types of measurement systems.

Successes and adaptations

Our initial interpretation of this situation based on the event report was a "recovery success". The measurement system was not functional after the maintenance task, but after this had been noticed, the system resumed to its normal state of functionality. When we asked about the successes regarding this task, the interviewee brought up the following:

- It was not forgotten to perform the maintenance task
- It was noticed that the measurement device was offline
- The mistake was reported

Even though the measurement device was left offline, the interviewee found that there is success in the fact that the maintenance task itself was done and not forgotten. The second success the interviewee found was that it was noticed that the measurement device was offline. The interviewee wasn't completely certain regarding how exactly was it found, but attributed the detection to coincidence. However, after further questions, the interviewee pointed out that the offline measurement would have been noticed sooner or later anyway: the statuses of the measurements are monitored constantly by multiple people. This seems to suggest that the activities in this particular case are organised in such a manner that this type of issue won't be unnoticed; however, it might require extra adaptive effort from someone else in the organisation to constantly be alert for unexpected statuses and be able to take action once something out of the ordinary is noticed.

The interviewee spoke most of the fact that the incident was reported and that the personnel is not afraid to report deficiencies or mistakes:

> *"It was appropriately reported that this had happened – if they had just gone and switched it back on again, no-one would have probably noticed anything. Reporting is done openly at our plant."*

When we asked to elaborate the reasons behind open reporting, the interviewee brought up the subjective experience of the personnel after the event scrutiny:

> *"If they get the feeling that it [reporting] wasn't so bad after all, then it supports being open in the future too."*

The interviewee found that those that participate in writing the event report, including operating experience personnel, are in an important role for retaining the openness of reporting. He emphasized that it is necessary to know the workers – their particular traits and how they react – and to be able to manage social interactions. The interviewee also mentioned the importance of the literary style of the report, which suggests that sufficient neutrality needs to be retained to avoid the impression of blaming. Maintaining and improving a good safety culture includes open reporting: in this sense the behaviour in this particular case illustrates how desirable cultural characteristics are manifested. Respectively, the social abilities of those participating in writing the event reports can be seen as one of the factors affecting the development of safety culture. Furthermore, the ability of the event report team to take human relations into consideration is adaptive by nature (see also chapter 2.1) and thus cannot necessarily be meaningfully formalised. Therefore this case illustrates the need for interpersonal adaptive capacity in enabling future success.

<u>Lessons learned</u>

The interviewee brought up that there were two practical lessons learned as a consequence of this event. First, a technical solution was proposed that would better notify about these kinds of situations; secondly there was addition to procedures that attempts to improve communication between departments to avoid memory lapses. We interpret these two lessons as predominantly "Safety-I"-type safety management, because they mainly focus on adding obstacles to failures. However, the reporting and handling of the reporting process itself may have the potential to contain lessons of "Safety-II"-type – to ensure that things go right – specifically, how was the investigation handled in such a manner that reporting is openly done in future, as discussed earlier.

<u>Overview</u>

In this case the researchers were surprised by the number of successes that the interviewee brought in relation to the event. The interviewee also found such successes that the researchers couldn't pick up from the event report. Even though it doesn't directly relate to the adverse event itself, one of the main findings discovered in relation to this case was the complex nature of the event reporting process. Namely, the comments of the interviewee suggest those that carry out and handle the event investigation process are not just passive outsiders, but are in fact active agents that affect and develop safety behaviour of the shop-floor workers. This has possible implications for event investigation activities: the investigators (i.e. operating experience staff, supervisors, and technical experts) require familiarity with the shop-floor workers, sufficient interpersonal adaptiveness and social skills to handle the investigation in such a way that the trade-off between the benefits from the investigation and ensuring future open reporting is managed appropriately.

Case 5: Restoring power feed to a measurement device

Case description

After a maintenance task at electric switchboards was completed, a power feed was inadvertently left unavailable which disabled a measurement device. Personnel from another department noticed that the power was off and notified about the issue. After this the power feed was restored. We interviewed a group manager who is familiar with the context but wasn't involved with the situation.

Successes and adaptations

Our initial conception of success based on reading the event report was that it is a "recovery success": the system was initially unavailable, but after detection, the functionality was fixed. Based on our initial reflections after reading the event report, we found three phases in the situation that contributed to this overall success:

1) Detecting the lack of power
2) Informing about the lack of power
3) Restoring power feed

When we asked about the detection of the lack of power, the interviewee found that the workers may experience a sense of success when they find out something abnormal. However the interviewee implied that in this particular case, the detection was too mundane to cause any significant sense of success – the lack of power is obvious and easy to notice, and it is not a particularly noteworthy event; on the other hand, if the worker had detected a significant anomaly, it would have been experienced much differently:

> *"In a way they do experience a feeling of success when they notice something abnormal… in this case the lack of power probably doesn't, but if they had for example noticed a smoking relay and prevented a fire then…"*

The interviewee agreed that informing about the lack of power can be considered a success of some sort. When we inquired whether it is easy to know how or who to inform about anomalies in this type of situations, the interviewee found it quite simple: the fitters inform the shift manager, who then relays the information forward. We interpret this as an established practice, which doesn't require performance adaptations from the individuals.

The interviewee wasn't aware of the details of how the power was restored; however, when the power came back up, it caused an electrical surge, which caused some damage to equipment under his responsibility. Because of this, the interviewee was reluctant to perceive the restoration of power a success. This highlights how different stakeholders see or experience success differently. In this particular case we see a "conflicted success" between the stakeholders: the restoration caused damage to the interviewee department's equipment, so from their perspective the restoration was a failure due to the way in which it was carried out. However, the department which handled the restoration can be seen successful because they did restore the power, which was their immediate goal. The interviewee contemplated that it probably wasn't known that restoring the power could break something.

Overall, the interviewee didn't find anything particularly special about the recovery situation. We assume the following factors might have contributed to this: the detection and notification of the anomaly wasn't very noteworthy; secondly, his department didn't handle the power restoration, therefore from his perspective, this aspect of success wasn't very relevant; finally, the restoration caused damage to equipment in their department. The interviewee summarized:

> *"It's a bit difficult to see anything where we could find positivity […] maybe one should look at it from the other department's perspective."*

Lessons learned

When discussing the possible lessons learned from this event, the interviewee didn't mention specific lessons; however, he brought up the time-correlation of various learning methods. According to the interviewee, the situation was discussed in a weekly meeting; the interviewee felt that the lessons are learned almost immediately from the moment itself, rather than from event reports, which are sometimes finished long after the event. This may indicate that event reports are by their nature lagging sources of information and something that the shop-floor workers probably don't actively rely on in terms of learning.

Overview

This case emphasizes the complex and systemic nature of success: there were partial and local successes during the recovery process and the recovery as a whole was successful, but not without issues. In this case there was a distinct stakeholder-dependence regarding what is considered a success. This also came up to some extent in the event report. Another thing this case illustrates is that the salience of the event may affect how the worker perceives the success: if the event is not significant, the success is also considered less significant. Similarly, if there's a failure in the situation, it may draw the attention away from the positive events.

Case 6: Making constructional improvements to a venting system

Case description

During a periodic pressure test a leak was located in the venting system. In this pressure test that is carried out at intervals of eight years a pressure of the whole system is increased temporarily to stress e.g., the equipment and pipelines in order to locate leaks and weak points of the system. The leak in the venting system was immediately observed by the test personnel and procedures for troubleshooting the problem and identifying the root cause of the leak was started. Required repairs were done for the venting system without causing mentioned delay on the outage. The interviewee had participated in the periodic pressure test in question but had not been the main responsible of handling the particular leakage.

Successes and adaptations

Initially, after reading the event report, we thought that the biggest success in the case was the fact that the observed leakage led to a larger scale of investigations revealing similar issues also elsewhere in the system (and even in another plant of the same type). We considered the success in this event report as "extraordinary success": after task (periodic testing and related maintenance work) completion, system functions better (weakness was identified and construction improved) than what was expected; or new learnings took place. When the interviewee was asked about the successes regarding the case, he brought up the following:

1) The periodic pressure test revealed the leakage
2) The timing was optimized regard to the possibilities to respond and handle the observed kind of situations/issues
3) Singular leakage led to a recognition of larger scale of similar weaknesses in the system
4) New improved construction was implemented that made also the monitoring of the system condition easier

According to the interviewee the first and the second success in this particular case are tightly connected to each other. The periodic testing is done to stress the system in order to find its weaknesses. The test functioned in its purpose and successfully revealed the injured structure. A success can be found in the fact that the pressure test managed to achieve its goals. Furthermore, as the pressure test was scheduled to be carried out during the outage, the organization was well-tuned and prepared to handle this particular kind of situations. The interviewee also mentioned that success of some sort was the handling of the bureaucracy and the expenses and costs that followed from the discovery. Another piece of a puzzle that worked well according to the interviewee was the communication and noticing relevant parties about the progress of the event.

Our original conception of the success in this case was the avenue of the observed leakage leading to a larger scale of investigations that then in the end revealed similar issues also elsewhere in the system. However, the interviewee did not perceive this progression particularly noteworthy. He referred it to be a normal procedure, part of good safety culture: when something like this is discovered it is not kept as an individual case. Instead, it should be assumed that there is a possibility of more issues, which is the reason why a larger investigation is always initiated. The interviewee summarized:

> *”If we find, let’s say from pipework x, some worrying reading and then identify this as a new kind of defect, something that we have not known of before… After that, according to our process, we would need to start thinking where else the same defect could appear. […] In this particular case of a leakage, this was just one part of the system that has dozens of similar constructions there.”*

The final success that the interviewee recognized in the case was the implementation of improved construction. The new construction made it possible to better monitor the object and through that also make certain what the condition is and if any maintenance is needed on it. This type of success could be considered something that prepares for the future or creates preconditions for future success, because it helps avoiding certain kind of failures in the system.

Lessons learned

When discussing with the interviewee about the possible lessons learned from this case, he mentioned few distinct ones. First being the importance and usefulness of the periodic tests even if they demand significant amount of resources from both personnel and economical points of view. The two others were connected to the handling of the situation. The experience of fluency of bureaucracy and directing the costs, and ease of communication and shared situation awareness. However, the interviewee was not able to specify any particular contributing factors for these experiences. The overall impression was that being part of the case and following the handling of and investigations regarding the situation had as a whole been a positive learning experience and source of motivation for the interviewee.

Overview
In this case many successes were identified, locating the leakage, discovering the resolution of the problem in the system and making constructional improvements that benefited also the condition monitoring in the future. However, as the interviewee was not the main actor in the case, the details behind the successes were not easily touched upon.

3.4 Field observations

Analysis methods
Our main focus during the field observations were on two complex lift tasks. The approach to observations was open and exploratory – we collected and noted any activity that took place during the observations, with a special focus on performance adaptations, unexpected conditions and potential successes. Brief interviews with shop-floor staff were also conducted when possible. After the field observations all researchers did independent analysis of their findings and attempted to relate their observations to the insights from the theoretical work; after that we reflected our findings together. A battery of follow-up questions was formed for each of the two interviewees with whom we discussed the two tasks we observed at the plant.

Task 1: Completion of a modernisation project involving heavy lifts

Task description
A major modernisation project was carried out in the turbine hall. This modernisation project was unique and involved tasks never done before at the plant. The project included both simple and routine tasks (e.g. welding, piping), and complex tasks such as transporting and lifting of heavy objects. We observed some of the heavy lifting tasks and afterwards we interviewed the person in charge of turbine hall equipment who was also responsible for carrying out the modernisation project.

Successes and adaptations
Overall the project was completed successfully. The most prominent success criterion that emerged from the responses of the interviewee was scheduling and cost: ensuring that the work proceeds within time constraints and doesn't exceed budget. In addition, both plant safety and occupational considerations came up during the interviews. Emphasizing these types of success criteria reflects the interviewee's position in the organisation as he plans and oversees the whole project rather than just executing one specific part of it.

When we discussed the factors that contributed to the successes, the interviewee specifically mentioned thorough preparation and organising the workforce appropriately as the main contributors. As a facilitator to carrying out the preparation successfully, the interviewee emphasized the importance of experience – both own experience and utilizing the experience of others. Even though the project as a whole was unprecedented and contained tasks of which the plant personnel had no previous experience in, the interviewee found that experience with the context, ideating with others and profound insight into the project helped with the preparation:

> *"We planned [the project] together, and I also contemplated a lot about all the possibilities and impossibilities that need to be prepared for to ensure that everything goes right"*

The interviewee also mentioned gathering information by discussing with colleagues that have experience about analogous projects:

> *"I also asked about other [big] projects at the plant: what has been useful, what needs to be taken into consideration. [...] How did they achieve schedule, what did it require. These experiences were then utilized."*

This may be an indication that interpersonal relations and general knowledge of the plant personnel is an important success contributor and a mean for experience transfer: being able to locate relevant people and discuss work-related questions with them.

According to the interviewee, a lot of the attention during planning went into organising the workforce: ensuring that correct human resources are available at the right time and to sufficient extent. Profound understanding of the task and previous were considered by the interviewee as the main contributors to organising the workforce. The interviewee summarized:

> *"When you know what you're doing, you also know what you need to do. Obviously, someone working for the first year wouldn't have been able to handle this. Experience definitely helps a lot."*

Altogether it seems that preparation for the project shows certain characteristics of adaptive learning processes. Because the project was unique, there were no clear guidelines of how to proceed, rather, information that could be useful appeared to be scattered within colleagues that have done similar (but not quite) projects, 3rd party experts, or needed to be created by expert personnel (such as the interviewee) by envisioning the task process and its possible contingencies, and applying personal experience. This selection of sources of information was then meaningfully integrated to create a functional project plan.

We also inquired whether any unexpected events or deviations from the initial plans occurred and how these were addressed. This was done in order to identify possible performance adaptations. During the interview the following situations came up:

1) The amount of asbestos at one of the work sites was more than expected
2) Problems with concrete moulding
3) During one of the lifts, noise was heard from the crane

In the first situation it was discovered that there was way more asbestos at one of the work sites than was expected. This caused the overall task to be completely halted. The issue was initially anticipated and a cleaning team was prepared, however this team wasn't present in its entirety at the day of the discovery and thus wasn't able to handle the unexpectedly large amount of work. It was decided to allocate appropriately licenced workers from other companies working at the plant to help with the cleaning operation. The solution can be seen to demonstrate flexibility in organising the work: Firstly, the project team managed to quickly locate suitable people at the plant, even from different companies, which probably suggests that there were sufficient communication channels between the organisations and departments. Secondly, in this acute situation, it was possible to utilize workforce not directly involved with the task. Linking to previous mentions by the interviewee that emphasized usefulness of communication with other parts of the organisation during project planning, this example suggests that effective communication can also be advantageous when it is needed to respond adaptively in an on-going situation. This may provide general indications regarding which preconditions have the potential to enable adaptive organising at the project level.

In the second situation there were some problems during concrete moulding tasks. The problems mostly related to the condition of the old concrete structures and the extent to which new structures needed to be moulded during the modernisation project. At a general level this potential issue was known already during the planning phase – a known uncertainty – however, it wasn't completely clear to all parties involved how to deal with it. After the main 3rd party contractor brought up the problem, the situation was discussed and solved with an on-site meeting with all parties involved there, as summarized by the interviewee:

> *"The most important thing is to go there and discuss concretely at the work site what the problem is and how to proceed. [...] When you discuss it together, everyone knows the situation, there's not going to be misunderstandings and the job will be done right."*

This unexpected event highlights that there can be situations that are inherently unpredictable and need to be dealt with as they occur. In this case, the situation was solved by means of on-the-spot reflection, which may suggest that one of the contributors to successful tasks is forming a shared and clear mind-set or model of the situation. Consequently, these shared mind-sets or models may help build the adaptive capacity that may contribute to coming up with useful solutions for the problems.

The third situation took place during one of the lifting tasks. Extraneous noise was heard from the crane, which caused the lifting to be immediately stopped. Experts from the crane manufacturer were present and investigated the situation. The problem was identified and fixed, and the lift was continued after a short delay of 10 minutes. This event can be interpreted as comprising of two types of success: the detection of the noise and having the crane experts in place to repair the problem. One of the researchers was present during the lift the noise was heard. Due to the overall noisiness of the environment and the extent of unfamiliar noises, the researcher couldn't distinguish the extraneous noise coming from the crane in that situation. The plant personnel, however, found it quite obvious. This may suggest that the plant personnel have become very familiar regarding what sounds are expected and what are out of the ordinary – in a sense they are sensitized to the specific noise signature of their environment and are thus able to distinguish such noises that are not normally part of it. It may also be possible that the crane noise was heard differently at different locations; in this case the success might also involve the communication process of informing about the anomaly to someone in charge. Overall, the detection success reflects the existence of relevant monitoring skills, which can be seen as an aspect of adaptive performance. Another success that can be seen in this situation was that the manufacturer experts were present and could fix the problem quickly. These experts are not present during the lifts by default, but are ordered there. The interviewee found that it was a result of the through planning process:

> *"I thought that, the crane is just something that may malfunction. If you don't anticipate and get the [maintenance] men there, it could cause delays and such."*

This suggests that being able to maintain requisite imagination and questioning attitude during the planning phase may contribute to successful completion of the task. In this case the project planning team identified that crane functionality is one of the basic assumptions behind the task, so thus manufacturer experts were ordered on-site to ensure that crane functions properly.

Finally, because this project involved over a dozen of 3rd party contractors from multiple countries, intercultural considerations and management of subcontractors played a part in this project. One of the main concerns the interviewee brought up was the multiplicity of languages spoken at the work site. There were some indications of language barriers between the plant personnel and 3rd party contractors. In order to prepare for this, measures such as ensuring that there are right interpreters available and holding induction trainings in personnel mother tongue were taken. In addition, there were indications of vigilance and adaptive behaviour that enabled better communication between personnel:

> *"The night shift manager told us that it [3rd party language proficiency] is a bit weak, but then we found a worker on night shift that speaks common language so the issue was solved."*

In this example the potential language barrier was solved by flexibly organising the work so that the language-proficient worker's abilities could be utilized.

Lessons learned

When we asked what were the most important lessons learned from the successful aspects of task, the interviewee mentioned preparation, deep insight into the project and collaboration:

> *"You should delve deep, really closely into what you're doing and think from many viewpoints. And ask a lot of questions – you can't do the job just by yourself."*

These basic principles were quite apparent when reflected against the responses of the interviewee in other questions.

We also inquired what methods are used to store or share lessons learned from these experiences. The interviewee brought up an informal practice that has been found very useful in some previous projects that was also applied in this particular case: a "work site journal" was kept where all activities were written down, including small details, problems and things that went well. This journal was then stored electronically for easy retrieval. A post-job review and feedback meeting with the main contractor were also held. The function of these meetings appeared to focus mostly on collecting experiences, which included both positives and negatives, but to our interpretation, the meetings were mainly about whether the parties agreed, but not on deeper discussions of the success contributors.

Overview

This case provides a unique insight to maintenance work and learning from success by illuminating the content of design and planning work of a large project. The case especially highlights the role of anticipation and pre-planning as the major factors of contributing to success. We found that creating meaningful project plan requires a thorough investigation into the substance matter, collaboration, imagination, questioning attitude and applying one's own experience. Because this particular job was unique and unprecedented, we saw the planning as a rather adaptive effort, which required imaginatively locating, gathering and integrating information from a variety of sources. Effective intra-organisational (and inter-organisational, especially if 3rd parties are involved) communication processes, both formal and informal were also found important in both planning the tasks. It was also found that in a complex project such as this, it is expected that it's not possible to consider or anticipate everything – some uncertainties are therefore known to exist beforehand. This furthermore seems to suggest that planning tasks isn't only about prescribing activities with to-the-letter compliance in mind, but it also involves creating preconditions to respond to unexpected situations. Overall, we see that there are potentially adaptive processes in the planning phase itself, and the planning phase may create preconditions for adaptive behaviour in other phases, and finally adaptations are carried out when the task is performed.

Task 2: Heavy lift at the reactor hall

<u>Task description</u>
We observed a heavy lift that was carried out in the reactor hall during the outage. In this particular task an object is lifted and moved to the revision platform. We observed the lift from the beginning until the point in which the object was laid on the revision platform. We were not able to observe pre-job briefing or post-job review. Likewise, some of the preparatory work had already taken place when we entered the reactor hall.

<u>Successes and adaptations</u>
Overall the lift succeeded normally with the exception of minor difficulties in the beginning of the task. This particular lift is a safety-critical task in which time and budget are not the defining factors for success. The interviewee found that success is achieved when one can immerse oneself and remain focused in the execution of the task itself, and that this creates the best prerequisites for completing the task successfully and safely. In addition, communication and team work aspects were also raised and discussed in the interview. All in all the answers of the interviewee reflected the hands-on operative level of the everyday maintenance work that he is involved.

According to the interviewee the most critical phase in the lift is the phase in which the object is slowly being lifted up. In this point making sure that nothing extraneous is attached to the object is the most crucial thing. The next phase is when the object is moved to a revision platform. The interviewee emphasized that during this phase communication is important to avoid any collisions because in the outage there are a lot of standalone equipment placed on floor level of the reactor hall. The final phase of the lift is when the object is lowered down to the revision platform, which is also very critical because the maintenance pit is extremely narrow. In this phase, the crane operator is almost totally dependent on the instructions of the others as there is no direct view from the crane cabin to the maintenance pit. In all these separate phases of the lift the whole team functions as the eyes and the ears of the crane operator. Being able to monitor and maintain the focus on the safe progression of the task is one of the main factors contributing to the success. The interviewee summarized the "focus on task at-hand":

> *"Then I will forget any timetables or schedules and try to concentrate on the work itself. It can take an hour or two but the most important is that it will succeed. Because when it succeeds, time does not matter. But if we fail it might be the end of this plant."*

Another important success contributor that clearly came up in the responses of the interviewee was team work and supporting each other. This topic was particularly important to the interviewee as he was approaching retirement and having the responsibility to train the new persons to follow him in his position. According to the interviewee the best way to learn is by doing it yourself. The challenge in the outage operation is that these real learning possibilities (e.g. for a particular type of heavy lifts) come only once a year or, depending on the work shift patterns, even more rarely. Therefore, the outage operation is definitely not everyday operation and thus transferring the knowledge about the details of the outage operation takes several years. This is why, according to the interviewee, it is important to remember that there are always many experienced people around that can be asked advice or help if needed. The interviewee also instructs and encourages his apprentices to improve themselves and their own work practices:

> *"Of course I always tell first how I do it and how it was taught to me and what are the current practices. But then I also always say that it is allowed to develop this. When I came here I [...] could see things in new light. I believe that the same applies also to these new ones that start no: there is always something to improve."*

We also inquired whether any unexpected situations or deviations from the task procedures occurred and how these were addressed. In this kind of unexpected situations the team usually need to adapt their performance to better fit the new conditions. As mentioned by the interviewee, the lift succeeded well. The only exception to the normal procedure was:

- The incorrect setup of crane's bridge when the gripper was attached to the object

In this situation it was discovered that the bridge of the crane was set up on wrong coordinates after the gripper had been attached to the object. The wrong positioning of the bridge was noticed by the group right after the work on fastening the gripper to the object had been finalized. This observation halted the whole lifting operation. The group gathered together to make an assessment of the situation. According to the interviewee, this inconvenient lapse took place because the lifting coordinates for the object in the crane in the two units of the plant are different and the bridge was accidently setup with the starting coordinates of the wrong unit. However, the situation was readily observed because according to the procedures, before starting the lift the right positioning of the crane is verified. The only possible solution in the situation was to detach the gripper from the object and move the bridge to the right coordinates. According to the interviewee, recovering from the incorrect positioning of the bridge succeeded well. He attributed this to experience and calmness:

> *"We have a lot of operating experience, and we have our heads screwed on tight: it is important that nobody loses nerves there and that we are rational. We have always time to take a moment and think again. It is important that if you have any doubts, we stop and consult the procedures. Nobody can forbid that from us."*

The calm response of the lifting group to the situation can be seen to demonstrate their professional skills and confidence to handle the problematic events that appear unexpectedly. The episode did not cause any remarkable delays on the overall schedule of the reactor work.

The lift was closed with a short post-job review on the radiophone among the participants. During the review, the progress of the lift was discussed together. Starting the task with the wrong bridge coordinates was discussed but also the later phases of the lift that went as planned. Afterwards, the interviewee also discussed separately with the crane operator in order to identify the further places for improvements and the lessons from the situation:

> *"Later still at the same night, we went this situation through together with the crane operator. I guess it bothered both of us a bit…"*

Overall it seems that the lifting group was able recover from the failure in the beginning of the task and hold their concentration on the task without letting the schedule or any other external pressure to disturb them. This also demonstrated a good stress tolerance of the persons involved. Furthermore, the observed episode shows that the participants were able to take a step back and professionally reflect their own performance in the situation and take the lessons from that.

<u>Lessons learned</u>

In the end, when we asked what were the most important lessons learned from the successful aspects of the task, the interviewee emphasized the meaning of fluent communication and collaboration as well as team spirit and trust. In general, the interviewee highlighted the openness and willingness of sharing experiences and giving feedback:

> *"I think it is always useful to say if the lift has gone well and succeeded. I mean succeeded normally and it is still worth of mentioning to everyone: thank the crane operator for good performance and that everything went according to the procedure. Because it shows that it is enough that we follow the procedure. We don't need to do any superman tricks, we just do as the procedure says, are rational and use common sense and we will succeed."*

The interviewee also reflected why learning from mistakes is so much easier than learning from success:

> *"I do not know… Maybe failing is still so much harder for everyone to go through than succeeding. Say, if a decade ago I did a good lift and nothing noteworthy happened… but if a decade ago everything had gone wrong, I will most likely remember it for rest of my life…"*

<u>Overview</u>

This lifting task we observed provides a new perspective on learning from success and complements nicely the modernization project observation. This case highlights the meaning of focusing on task at hand and the aspects of collaboration and team work and team-spirit. In other words, it is about the practical maintenance work at the operative level. The case also demonstrates (for better or for worse) the role of procedures in successful task performance. It seems that in this kind of task that is well-known that if nothing anomalous appears during the task, following the procedure is enough to succeed. In this particular case the identified failure situation was such that recovering back to the normal task procedure was relatively straightforward. However, after the failure, performing the rest of the lift successfully demonstrated the capability to reorient and handle the work stress caused by the initial problems. Overall, the lift was considered successful as a whole.

3.5 Success stories from the field

In addition to the event reports and the tasks we observed, we also identified successes in other contexts. During the observations we attempted to remain open for noticing various successful actions and conditions. In the interviews we either specifically asked for concrete examples of things that had been successful or the interviewers spontaneously brought them up. These successes included both reactive actions to contingencies and proactive improvements to work practices or technological systems, and actions taken to support adaptive performance. In this chapter we summarize some of these "success stories" and propose our interpretation of them.

Improving the ergonomics of remote crane operation

<u>Situation</u>
The researchers were observing general activities and work conditions at the plant. All three researchers took note of this solution to improve the ergonomics.

<u>Description</u>
A heavy-duty crane used at the plant is operable from both the cabin and via remote control. The crane uses a scale to indicate what load is being applied. The load indication was, however, by original design, only available in the crane cabin because scale display was located there. This meant that when operating the crane remotely, information from the scale wasn't directly available to the crane operator. An interviewee brought up how the lack of scale display requires extra effort from the crane operators, especially with light payloads:

> *"If you're lifting something [light] and you're standing right next to it, you don't have any idea if the load gets stuck somewhere without the scale because the crane is so numb."*

Changing the actual technological design of the scale system was considered prohibitive due to the required effort. A technologically independent solution was thus conceived: a camera was mounted near the display inside the crane cabin and the image of the scale display was shown on a large television screen outside the cabin. This made it possible for the operators to see the load indication while operating the crane remotely.

<u>Interpretation</u>
To our interpretation, this situation involves multiple aspects to success. Firstly, it can be considered an "extraordinary" success: the crane as such was usable and in a "normal" state before, but after this addition, its usability became better than initially specified. Secondly, the unavailability of the scale information to the crane operator can be seen to require extra adaptive effort from the whole team: for example, it might be required that there's a person in the cabin monitoring the display and communicating the state to the operator or the crane operator would have to pay extra attention to make sure that the load doesn't get stuck anywhere. The addition of the external monitor decreases this extra adaptive effort, which can be seen a success. The success exhibited in this situation wasn't necessarily systemic because a complete overhaul of the system wasn't initiated – in this sense it might be interpreted rather as a workaround or "optimisation of a non-optimal environment". However, the modification was pragmatic and practical, and its apparent simplicity allowed it to be actually implemented and with relatively little effort. This situation also demonstrates multiple types of adaptive performance such as proactively improving work conditions, coming up with an innovative solution to an inherent problem, and managing to create a solution that sufficiently satisfies

key constraints that were set to the modification of the crane (i.e. the extent of financial and bureaucratic effort).

Team-spirit enhancing toolbox talk at work site

Situation

One of the researchers was observing a lifting task along with the plant's own observer.

Description

Just before the execution of a demanding and complex lifting task, the team responsible for carrying out the lift gathered in a circle a few meters away from the crowd of other workers surrounding the work site and held a particularly memorable toolbox talk. The talk was held by crane operator who also led the lifting team. The operator talked vividly of how the task should be carried out, emphasized his message with clear and strong gestures (e.g. using his tone of voice and hands to describe how a smooth lifting process would proceed). The operator also reminded the workers to focus on the team and not be distracted by outsiders by using plant's observer standing nearby as an example: *"don't pay attention to him, pay attention to us"*. Interestingly, even though the talk was held in a foreign language spoken only by the lifting team members, both the observing researcher and the plant's observer agreed that the message came clear regardless of the language barrier. The tool box talk ended with fist bumps between the crane operator and the other team members.

Interpretation

As an opposite of merely factual pre-job briefings or toolbox talks that may sometimes appear dull, this particular toolbox talk demonstrated the potential of this practice to motivate team members, build team-spirit and perhaps create a heightened sense of awareness or concentration. In this sense, it could be argued that the toolbox talk may have contributed to the successful execution of the lifting task. It was, however, the task leader's ability or personality that enabled holding such a talk in a credible way – how to hold an inspiring toolbox talk is not something that can be instructed mechanistically – this itself requires human contribution. The ability to carry out such a toolbox talk may also be a reflection of interpersonal adaptability: being able to understand the requirements of the team members before a demanding task. This suggests that all beneficial aspects to job preparation activities can't be completely formalized. Although purely an anecdotal observation, the lifting team did work very smoothly and without any apparent hiccups.

Plant personnel interest in each other's work tasks

Situation

Researchers were observing a rare and spectacular lifting task along with the operating experience personnel.

Description

Before the lifting task begun, the area where the lift takes place was cleared and secured by security personnel. At a safe distance, a crowd of plant personnel was observing the lifting task. One of the operating experience specialists commented that this is common: people not involved in a particular task are often interested and wish to see the task being performed; on the other hand, he also expressed his concern that this extra interest most likely only applies to especially exciting, major tasks and that smaller tasks largely remain overlooked.

Interpretation
The personnel's interest towards activities that don't directly concern their own tasks may provide a useful learning opportunity: the personnel become more aware of the other parts of the sociotechnical system they are working in. This includes both technical systems, but also their co-workers and working practices of other departments. This transcendence of interest can be seen both as a potential mechanism for success and as a result of individual's adaptive performance (i.e. engaging in extra-role behaviour by demonstrating interest in tasks outside their explicit task requirements). However, as the operating experience specialist mentioned, this interest most likely isn't global and only manifests in relation to spectacular tasks. In this particular case, the plant personnel recognized the task as rare and demanding, and this caused it to gain a lot of attention. In summary, even though in principle this particular tendency has desirable qualities, its limited scope probably limits its usefulness as a learning method.

Sense of "ownership" of technical systems

Situation
Interview of a group manager.

Description
When we asked about successful tasks or situations generally, the group manager remembered a situation during outage when a circuit board of a technical system was malfunctioning and needed to be fixed. Experts had to be called in from home to repair the system. The interviewee told that the situation was demanding because the malfunction could have caused delays in scheduling, but the workers handled the situation well:

> *"The guys were flexible and came from home. They kind of consider the systems as theirs."*

Interpretation
This situation describes an extraordinary and demanding event during which extra adaptiveness from the workers was required. The workers needed to deal with the surprising work task during their off-duty hours and cope with task difficulty. The interviewee implied that a positive contributory factor to workers' flexibility was their sense of "ownership" of the systems they are experts of. This may indicate extra-role behaviour which is a type of adaptive behaviour: regardless of whether the workers are formally required to do special off-duty jobs like this, they find it natural because it's "their" system that's malfunctioning. Such sense of responsibility also reflects desirable characteristics of good safety culture.

Achieving success together as a team

Situation
Interview of a group manager.

Description
When the interviewee was asked about successful experiences, he remembered a particularly demanding situation where success was a team effort. Their department was assigned to finish a pending overhaul task of a complicated technological system. The interviewee told that many people from his group participated in the task: designers, fitters, and in addition himself as the group manager. The task was urgent, there were constant inquiries about the task status, and difficult, requiring learning of new things by the designers. To facilitate the designers' work, the group manager calmed down the situation and ensured undisturbed working environment for the designers by blocking external disturbances. After the design process was

finished, all the participants, including both the designers, the group manager, and the fitters were present when the system was physically installed and it was confirmed that it was functioning correctly. The interviewee found that they performed very well as a group:

> *"We were all happy about what we accomplished together in this task. I like these kinds of cases. […] Even though there were different people involved, actually working together bonds the people. This also created a feeling of having succeeded."*

<u>Interpretation</u>
This particular case illustrates a situation where success was created as a joint effort of the whole team. This emphasizes the potential importance of team-level phenomena as a contributor to success. For example, in this task everyone knew their role and it was ensured that each can carry out their jobs as good as possible. In addition the case shows the possible social effects of positive outcomes: the interviewee brought up that the team "bonded" due to this demanding and successful work task. This suggests that outcomes that result in changes of social relations may also be of interest when discussing learning from successes.

Implementing a document repository that supports problem solving

<u>Situation</u>
Interview of an IT specialist.

<u>Description</u>
After having established that work at the IT department involves a lot of problem solving activities – some of which is time-critical – the researchers asked about what practices are there that support problem solving. The interviewee found that quick and easy access to documentation is important:

> *"In our profession, speed is of the essence; that we solve the problem quickly. If there's a problem, there's no time to start googling."*

The interviewee then described their informal practice of maintaining a central data repository that consisted of simple and well-organised documentations of the IT systems. The interviewee told that these documentations ranged from short practical instructions (e.g. how to do simple tasks such as changing parameters on specific systems or how to switch servers on or off) to manufacturer manuals. These documents were collected over time from sources such as manufacturers, trainings, or from own or collective experience of the team. When we asked the interviewee whether this kind of practice was also applicable to other departments than IT, he emphasized that quick and easy, electronic access to instructions, manuals etc. is important for effective problem solving.

<u>Interpretation</u>
This story describes an informal knowledge sharing and preservation practice within the IT department. By enabling easy access to basic things – that may also be difficult to find or may itself require problem solving – the problems can be solved quicker. This may suggest that the implementation of general practices that relate to basic operations, adaptive capacity may in fact be improved due to better distribution of resources. The construction of the central repository of well-organised good practices can also be seen as a product of adaptive performance: as the workers solve problems, they create good practices or "tricks of the trade" that are then documented and stored in this repository.

3.6 Discussion on case study at plant A

Overall, we observed that the interviewees were rather good at identifying successes in their work. We found numerous aspects to defining and characterizing success in the interviews of the nuclear power plant personnel. Many aspects of success that we discussed in the theoretical part of this report (see chapter 2.2) came up during the interview, but also several approaches to success emerged that we hadn’t previously identified. One of the most prevalent success criterions was the extent of which the outcome was compliant with the plans. This reflects the procedure-orientation of the industry: the predefined plans are the main source of information that describes the extent of success of the outcome. Direct feedback from a relevant stakeholder was also considered one of the indicators of success. This indicator, however, is most likely biased because success-related feedback is rarer than the one related to failure. In addition, keeping schedule was seen important. Similar to our theoretical exercise in chapter 2.2.1, the interviewees found success in recovery activities; this was specifically manifested in problem-solving activities.

Some of the approaches to success the interviewees brought up were related to adaptive behaviour. For example, observing something significant, such as an anomaly, was considered a success by some interviewees. This relates the adaptive ability to monitor: being able to understand and make sense of what is happening in the environment. Furthermore, creating something new was considered success. This can be related to either proactive or reactive adaptive behaviour. The case of improving crane ergonomics illustrates such behaviour: the personnel proactively created something new in order to create better preconditions for future success. We also noticed in many cases how various types of adaptations contributed to success. For example, in the case of the modernisation project, anticipation played an important role in the successful completion of the project. Similarly, extra-role behaviour was seen as a major contributor to some of the success stories we identified.

The success criteria brought up by the interviewees that relate most obviously to safety were number of incidents or event reports. It was considered that a task is successful if these indicators don’t respond. These indicators reflect safety outcomes rather than safety potential and are therefore somewhat lacking (see also chapter 2.2.4). In this sense the interviewees didn’t at least explicitly relate success to the more systemic safety indicators as we attempted to do in the theoretical section. On the other hand, most of the interviewees were shop-floor workers that would perhaps experience safety consequences first-hand, so therefore it may be natural to consider safety from the outcomes point of view. In addition it must be noted that we didn’t explicitly ask about safety-related success criteria, nor did we attempt to reveal how the interviewees perceive safety. Therefore, the safety-related success criteria that came up during the interviews may not be representative of all aspects of safety that are recognised by the plant personnel.

Motivated by our discussions of subjective or socially constructed aspect of success (chapter 2.2.6), we also attempted to uncover such success criteria that are not objective or clearly measurable. We found that it was difficult for the interviewees to explicate these, which was probably at least partly due to our possibly lacking interview scheme and because the nuclear industry culture is rather procedure-oriented. Regardless, the interviewees did mention professional pride which can be seen as something that affects the aspiration levels in the organisation. Interestingly, several interviewees brought up sense of satisfaction or the feeling of having succeeded. For example, one interviewee mentioned that detecting dangerous abnormalities may create a feeling of having succeeded; another interviewee told that it felt satisfying to be able to help out a colleague; yet another interviewee emphasized managing social effects of event investigations. Furthermore, many of the interviewees emphasized the importance of good team-spirit as a prerequisite for good performance. Some success stories in chapter 3.5 illustrated how success was achieved together – these successes may have an effect on team processes. Altogether, this may mean that there’s an aspect to success we haven’t reviewed in theoretical section, namely, the socio-affective approach to success. This would involve such phenomena as retaining individual and group motivation, team-spirit or sense of purpose – all loosely related to work-related well-being.

We also found indications and examples of success that are not universally shared but are rather conflicting in some fashion. Some of the sources of conflict that came up during the study were different stakeholder perspectives (e.g. different departments may perceive successfulness of a task differently), or when the task contained partial successes which coexisted with failures, or when there was simply lack of feedback which caused confusion or uncertainty of whether something has been successful or not. These are aspects to be considered when doing data collection: relying on single information sources may give a limited understanding of what actually was success and how it was achieved.

When we attempted to find successes and adaptive performances from the event reports, we found that the difficulty of finding anything meaningful varied between the cases: in some cases it was quite obvious even in the reports that there were successful actions or decisions made; in others they were either non-existent or hidden. We also found that to a surprisingly large extent our assumptions of what were the successful events in the report agreed with those of the interviewees. The interviewees, however, brought up many pieces of detailed information not available in the event reports, which demonstrated that attempting to create a thorough understanding of the situation based on the report only is most likely futile – especially if the situation has been complex with multiple actors involved.

The following points summarize the main findings that came up during the analysis of the event reports and the corresponding follow-up interviews:

- The successes found in event reports related mostly to either recovery or creation of something new
- In many cases successes were considered mundane and failure took precedence in terms of attention – however, after explicitly asking for successes, the interviewees did recognize some
- Successes could manifest themselves either immediately (e.g. fixing an acute problem, achieving short-term goal) or latently (e.g. removing an underlying problem, creating better preconditions for future tasks)
- Event reports didn’t contain information about all successful aspects of the task, some were covert and potentially tacitly embedded within the general knowledge of the personnel
- Most of the lessons learned brought up by the interviewee or in the report appeared to be focused on dealing with the things that went wrong (i.e. “Safety-I” approach).
- In complex situations, identifying and understanding the successes most likely requires laborious scrutiny
- Participants may have differing views on success even if the task overall is a success

We found it challenging to identify adaptive performance in the interviews and event reports. Although we attempted to refer to the insights of the theory (as discussed in chapter 2.1), most of the manifestations of adaptations seemed to emerge by chance rather than systematic scrutiny. Our theoretical overview of adaptive performance, however, may have helped to identify adaptive performance if indication of it was mentioned by the interviewee. There also seemed to be certain job or task correlation between how easy it is to find adaptations. For example, when we interviewed the IT expert (in case 3) we found that it might be easier to identify adaptive performance in that department because a large portion of the job done there is complex and involves problem-solving. This is also somewhat in line with the findings presented in chapter 2.1, which suggested that the prevalence of different types of adaptive performance may vary between occupations; it may also be a possibility that some job tasks don't require much adaptive performance to ensure success. We also attempted to understand what types of adaptations are commonly done by asking about the challenging aspects of the job tasks from the interviewees. Overall, in reference to the adaptive performance types presented in Table 1, almost all of the adaptive behaviours or abilities were demonstrated to some extent in our findings; however, collecting and cross-validating adaptive performance in relation to this table was not within the scope of this project and therefore it can't be validated as an exhaustive framework for capturing adaptations in nuclear maintenance. Nevertheless, the table seems to give a sensible starting point for capturing practical manifestations of different types of adaptive performance.

As opposed to the failure-oriented event reports, field observations brought up a different view to successes. We observed two major tasks: a modernisation project that was unique and unprecedented and a reactor hall lift that was relatively routine and well-understood. In the modernization project we found that some evidence that adaptiveness is required when attempting to anticipate and prepare for the task. This involved, for example, imaginatively integrating knowledge from various loosely-related tasks regarding how success had been achieved there in order to create preconditions for the success. In relation to this task it was also clearly expected that there are uncertainties and that unexpected issues may occur; thus, creating the ability to manage the unexpected was an important part of the task. The reactor hall lift task, on the other hand, had precise, established procedures and the environment seemed more stable and there were fewer uncertainties: following the procedures to the point would result in the success. In summary, while in both of the tasks were overall successes, the success contributors appear to be different: in the reactor hall lift the essence was to carry out the existing procedures to the point and keep an eye on any contingencies in the environment that could obstruct this, while in the modernisation project the essence was to actually build usable procedures and plans.

In terms of applying observations as a method for identifying successes or success contributors we found that they complement other methods nicely. For example, observations can provide ideas for further questions; allow the detection of "tacit" things (e.g. atmosphere, overall climate at the work site) that aren't often conveyed in written material; or enable identifying such details that wouldn't be otherwise noticed. However, we also noticed that specific expertise or deep understanding of the context is required; without that, observations are of limited usefulness as a source of information. In other words, insight from an expert (i.e. a retrospective interview or reflection during the execution of the task) is needed to validate and elaborate the findings of a non-expert observer.

In the interviews we also discussed what kinds of practices there are in the plant in terms of learning and sharing information. We found that there were many formal and informal learning practices ranging from casual "coffee-table discussions" to organisation-wide training programs. We also found that both formal and informal practices involved aspects that made them potentially useful for learning from successes. For example, some formal practices such as post-job reviews already required discussing successful aspects of the finished task. There were, however, some indications in the interviews, that successes aren't commonly discussed very in-depth, but rather collected and agreed upon, which may perhaps be a more intuitive approach to dealing with a successful task. However, this may also mean that actually learning from successes might not be particularly effective. In addition, merely collecting successes without discussing their meaning may predispose to drift or complacency. We didn't manage to observe any post-job reviews and therefore couldn't confirm how tasks are actually scrutinized. Part of the problem may be that nuclear industry post-job reviews as defined by DoE (2009) mostly emphasize identifying and recording things that went well, but don't explicitly specify how these successes should be applied for learning purposes. This suggests that further development of post-job review practices may be one potential approach to promoting learning from success. For example, systematic investigation into the reasons or contributors behind the successes might be a potential approach to improving post-job reviews; furthermore, applying insights from studies of success-oriented after-event reviews may also be beneficial (see e.g. Ellis, 2012; Ellis & Davidi, 2005; Ellis et al., 2006). We also collected a multitude of interesting "success stories" during the interviews and field observations, as presented in chapter 3.5. Although some of the interviewees mentioned that some aspects of these situations were discussed within teams or groups, it was unclear whether these cases were extensively discussed from success point of view. We assume that similar, successful events take constantly place that are not scrutinized nor perhaps even noted. This may mean that the contributory factors that make such successes possible might not be shared and thus further fostered.

There were also indications of information that is embedded within people or other social structures such as informal practices. Many interviewees emphasized that it is important to be able to find correct people and to collaborate with colleagues from different departments to create the required information for a particular situation. In fact, it seems that in plant A, asking help from a colleague is a practice that is employed routinely by the personnel. This demonstrates that a lot of the information is not explicit and codified to formal organisational practices but is available through other means. Some interviewees emphasized that it is important to codify this knowledge to explicit form (i.e. create procedures out of informal, good practices) instead of allowing it to remain as tacit knowledge. Others pointed out that some knowledge, such as individual experience, might not be possible to store into procedures or instructions. Altogether these experiences, albeit anecdotal, suggest that it may be necessary to make a distinction between information that is best stored in codified storages and information that is best stored tacitly. Managing of both implicit and explicit knowledge may be required to sufficiently enable learning from successes. In addition, it may be required that the experts of the tasks participate closely in learning from success activities because it is likely that outsiders are not able to grasp the tacit knowledge that is involved.

4 Empirical study at plant B

This explorative study aimed at investigating the concept of success how it is perceived, pursued, recognised at the nuclear power plan B, the study can be summarised in four steps:

1) Information definition, case selection
    - In this step we select/define the main topics that should guide the data collection to establish an empirical basis for development of principles for capturing successful performance. This work is based on a first survey of the literature on the subject and the ideas expressed in the previous chapter.
    - We identify potential situations for data collection, situations where we believe it may be possible to individuate successful adaptations.

2) Data collection
    - In this step we determine the most appropriate data collections methods (interviews, observations, event reports), for the various situations.
    - After identification of the methods for gathering data formulate the guidelines, for example formulate the questions for semi-structured interviews, and aspects to observe. The guides should ensure that the data collected will reflect the data needed to answer the research questions.
    - Data gathering in the field.

3) Analysis
    - Aggregate and structure the data obtained from the observations, interviews to answer the research questions. Note that in analysing the activities, what were not considered as a success by an interviewee, may be seen as successful – and vice versa.
    - A thematic analysis approach (e.g. Braun & Clarke, 2006); generally considered useful for identifying and analysing patterns (referred to as themes) within a dataset.
    - Identification of types of adaptations.

4) Formulation
    - Formulate principles for capturing successful performance adaptations.
    - Adapt the formulations to the language applied in "Operational Experience" processes.

There are several possible sources of information about in-the-field successful adaptations: direct observation of tasks and follow-up interviews to further penetrate some aspects; in-depth interviews of people on socio-technical aspects concerning adaptations and success; reviewing events reports for successful adaptations and follow-up interviews of involved people; conducting specific workshops.

In this study we have focused our observations on *present* adaptation and the *present* environment supporting successes. However, although many successes are immediate and sprung out from on-the-spot adaptations, recent observations suggests that some successes seem to origin from past adaptations, while some present adaptations may provide a future success. In the following we are using the term adaptation with a general meaning, indicating both a solving a problem for compensating a non-optimal situation (like inadequate resources), or finding an innovative way to do things.

Maintenance activities have been chosen as a target for the data collection at plant B, as presented later those activities, for their nature, can be theatre of several adaptations. Besides there was the opportunity presented by an outage in a suitable period for the study, and thus putting us in the condition to possibly observe adaptations.

4.1 Data collection

Data were collected in the period 23-25 June, 2015 between 07:00 and 17:00 from the three maintenance departments: Instrumentation and Control (I&C), Mechanical and Electrical. Data were collected by three researchers, mainly via observations and interviews. We carried out field observations with follow-up interviews and semi-structured interviews. In order of maximising the number of captured aspects and details, and to minimize misunderstandings, all three researchers were present at all occasions.

Due to the changing nature (variability) of the schedule and emerging issues of maintenance tasks in the preparations of the reactor start-up, it was not wholly decided in advance which tasks to be observed, and whom to interview.

This flexibility in planning, on the fly, was agreed with the team-leaders. For each day of the data collection period, in the morning briefings, the researchers consulted the planners to identify the jobs that seemed best suited for observations (complex, non-routine, trouble shooting tasks had priority). The data collection plan was hence adapted during the days, depending on what actually occurred. Various people, more or less experienced, were involved in performing the tasks observed, mainly coming from the three different departments, employees at the plant B and/or work force from contractors. Table 5 summarises the observations and interviews carried out during the three days.

Table 5. Overview of data collected at Plant B. Note. The concepts field observation and meeting observations refer to observations performed in–the-field and during meeting in meeting rooms, respectively.

ID	Type of data collection	Duration (approx.)	Details
1	Field observation + 2 follow-up interviews related to the observed task	12 hours	Task: maintenance of a seawater intake cooling pump, due to deviations (leakage and abnormal noise) were identified during the night. Involved personnel: • 2 mechanics, plant B employees • 2 mechanics contractors • 2 mechanical engineers • 2 electricians • 1 person, cleaning services
2	Meeting Observation	~10	Meeting: afternoon Instrument group briefing, at shift turn-over 10 persons involved
3	Meeting Observation	15 min.	Meeting: morning meeting for Instrument & Control 10 persons involved
4	Field observation	30 min.	Task: troubleshooting of a valve limit switch related to a turbine Involved personnel: • 1 plant B employee • 1 contractor • 1 supervisor
5	Field observation + interview	~40 min.	Task: pump electrical motor installation after the maintenance task from the previous day (1) Involved personnel: • 2 electricians
6	Field observation + interviews before and after the task	2 hours	Task: troubleshooting of a valve at the demineralization plant Involved personnel: • 2 Engineers (I & C)
7	Separate interview	20-25 min.	Involved personnel: • 1 employee of the mechanical department, working in the maintenance team for diesel engine service
8	Separate interview	30 min.	Involved personnel: • Manager of the mechanical group

4.2 Data analysis method

The analysis starts from the raw data collected applying the guidelines in Appendix 2. The starting element for the analysis is the *observed task*, and the first step is to assemble the acquired information.

<u>Step 1. Establishment of the complete event sequence (chronicle of what happened)</u>
Input: Raw data from the field
Output: Structured Task Description

In this first step analysis we proceed to

a. Combine observations and interview data.
b. Link additional related information from event reports and available documentation.

c. Order by event sequence.

In addition to general information concerning the observed task, a sequence of activities, pieces of interviews, sorted by time, Table 6 shows an example.

Table 6. Example of segment of information about one observed task, 23 June 2015

Time	If Observation: Job/Activity If Interview: Topic	Successful performance adaptations (“Now factors)	Factors contributing to successful performance adaptations (“background factors)	Personal Comment
7:45	…			
8:00	They (4 field operators are in the room) start to remove 2 supporting rods from area 1 to area 2, see Figure 1. They notice oil stains in the area adjacent to the pump (P4 in figure 1), they call a cleaner to clean the area.	Notifying the oil stain and make preparations to have a clean work area.		It’s always the team leader who controls the lifting. The cleaning is not mandatory, but a positive action to prepare for success.
8:10	…			

The first column contains the time stamp for an action or a topic discussed in the interview. The second column contains a description of what has been observed. The following columns are annotations coming from the Part V of the Data Collection Guide, anything that has to do with assessment of the task performance process (e.g. success or failure, not necessarily using these words), like delays, re-scheduling, etc.; challenges they encounter and manage during task performance; factors that promote task performance – including chance factors; Errors – and how they are assessed and corrected; Procedures, communication tools, etc.; successes the observers notice – even if the task performers may not have a similar conception. It is noted whether these were observed, or described by an interviewee. The reasons for why these are considered *success factors*, is also specified. Relevant documentation can be referred and linked to in those fields.

The information content at this step can be summarised, in abstract, in this way: The type of a task, with its actual goal, actual motivations, actual context, time, etc.

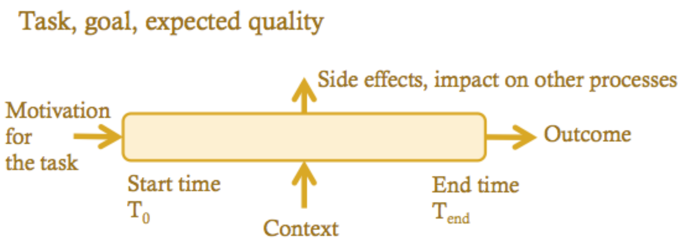

Figure 6. Summary of general information collected by observation of a task, the rectangle represents the description of what occurred during the task (see the *structured task description* below).

Conceptually the information about a task is places on a time line, with pieces of information (roughly one for each row of the table 4) from interviews or field notes from the observers, organised in a *structured task description*:

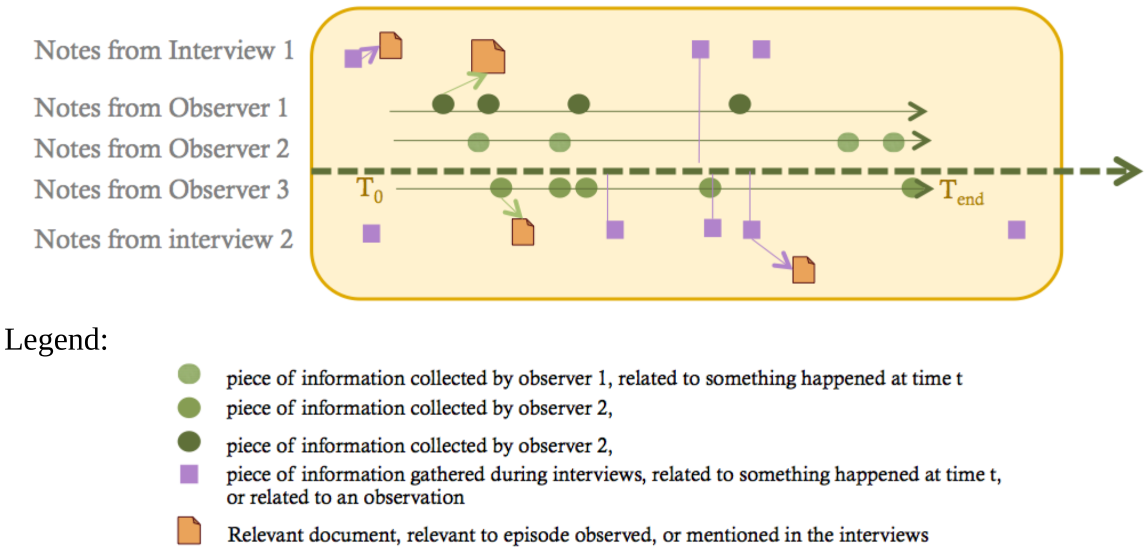

Figure 7. Conceptual overview of the collected information organised along a time line (*structured task description*)

Step 2. Identification of success episodes
Input: Structured task description
Output: Collections of TPSs

The second step is to identify success occurrences, and to understand the actual factors behind this. With this approach our main attention is on what is implemented on-the-spot, thus not the success factors foreseen in the procedures. In this phase a set of principles is developed, and thus supporting also the specific understanding of what a success is within the domain of NPP maintenance.
The base for this second step is the structured description of the task, as obtained from the previous step.

A. Identify successful occurrences:
   1) First delineation: include all parts of the task-performance process in which *"errors"* (clear safety breaches based on operator actions) were not recorded.
   2) Second delineation, based on the segments of the task-performance process resulting from the first delineation: Identify *unforeseen occurrences*, which required adaptation and where handled "successfully". Look for situations that were not expected/foreseen to occur, but which had to be dealt with.
   3) Look for activities heavily involving *human cognitive abilities*, involving human ingenuity like:
      - Planning, coordination, execution monitoring and follow up
      - Resource management (especially when the resources are concurrently used)
      - Cooperation, communication with remote groups
      - Decision-making
      - Sense-making (see e.g. Weick, 2009, p. 55)
      - Problem solving (e.g. diagnoses, including also creative use of tools)
      - Interpretation (e.g. when the procedures are written as high level recommendations)

At this point the observed task has been split in episodes of 'success', those that were performed particularly well (some value of implicit or explicit performance parameter was over the average, related to the level of task description, or judged by the team and/or the observers expertise), or they created more favourable conditions for the following/depending/monitored activities to be carried out. This aggregated element is named Task-Performance Sequence (TPS).

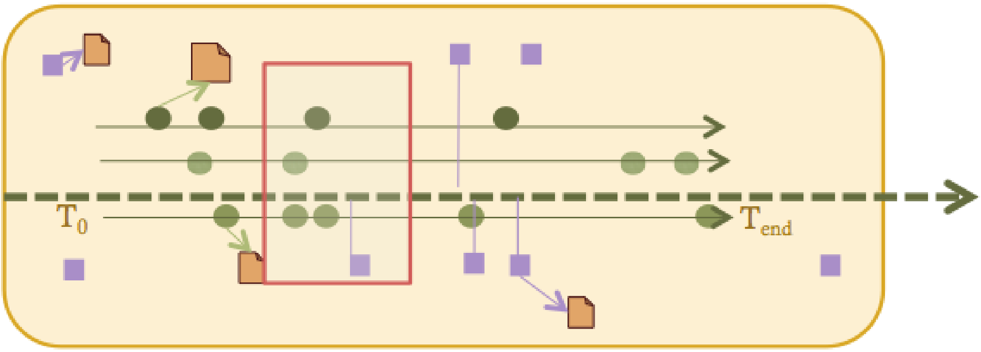

Figure 8. Task Performance Sequence (TPS) identified in a task performance timeline

B. For each identified success occurrence (TPS), document the success and its factors
   1) Document *basic information* about the task-performance sequence (TPS)
      a. Specify to which overall task the TPS belongs.
      b. Specify when the TPS took place
      c. Describe the content of the TPS
      d. Specify to what extent the TPS covers a routine occurrence or an unexpected event
      e. Specify the significance of the success in terms of safety and/or efficiency
   2) Document what *criteria* you used in the previous step (1.v.) to assess the success:
      a. Document your subjective, domain specific criteria for assessing the TPS to describe a success
      b. Describe the overall/generic (subjective) criterion/criteria you applied in the subjective judgement.
      c. Note if your judgement of the TPS being successful is based on Identification of a problem, Decision making, Implementation (of the decision), and/or the Outcome of the TPS, affecting other TPS in the same observation, or other process extern to the observation.
      d. Did the TPS result in an "expected outcome" or and innovative outcome (i.e., was the solution better/smarter than expected).
      e. If possible, specify if the task-performer considered the TPS as a success, as well as the reason behind his/her judgement.
      f. Assess the selected sequence using criteria emerged from the theory review (see chapter 2)
   3) Document the *framework conditions for the assessment*, the TPS is classified a success:
      a. Based on information available to who has assessed the success due to his/her position in the organisation (e.g. task performer, manager), and specify the position.

   b. Based on information available at a later time in relation to the end of the TPS (e.g. right after performance, two years later), specify when the assessment has been done.
4) Document *contextual elements contributing to the success*, distinguishing between direct and root causes, if possible. (Why it happened and why it was possible, What enabled maintenance personnel succeed in their work. One of the guiding questions might be: What *would be needed to reproduce the success in another organisation /organisation unit?)*
   a. Distinguish between successes due to regulations from success due to adaptation (if possible). Then indicate:
   b. *Organisational* factors that contributed to the success (e.g. work processes),
   c. *Technological* factors (e.g. tools available)
   d. *Human* factors: Performer characteristics (e.g. competence, familiarity with each other) that contributed.
   e. *Chance* factors
5) If possible, compare the observation to precedent experiences (see the section 'Variations (now-then)' in the table in Appendix 2) - or, in case when performing above the average performance, with the detail of task description, or by expertise judgment.
   a. What are the differences and similarities between the two task-performance processes?
   b. Why did "whatever went wrong then" not happen during the observation?
   c. Why the 'over the average' happened in this case?

The information elaborated at this point is collected in a table, a table for each TPS, (see Appendix 3).

Conceptually from each *structured task description* (input to this phase) a set of TPS's are identified and documented. It could be that none are identified, but it can be expected that one or more TPSs are identified as valid candidates for learning.

The process of identifying and documenting a set if TPS's is visualized in Figure 9. The TPS can be associated to various types of successes such as: a good outcome; high performance (above average); or positive side effects (on other processes). They may also interact positively with each other such that the good outcome of one TPS actually enables another TPS, or further enhance the performance of other TPS's.

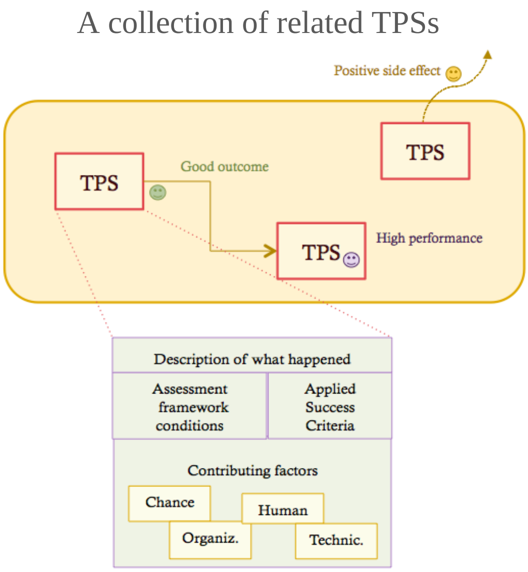

Figure 9 Overview of information describing a TPS and possible relations with other TPSs. TPS are labelled with a type of success

<u>Step 3. Synthesis of results summary</u>
Input: Collections of TPSs
Output: Results

For the study of Plant B results are then extracted from the collection of TPS. The analysis is at present only partial and first results are reported in the following.

The study at Plant B this year has been concerned essentially on the concept of success, aiming at understanding how it happens, how it is considered today in everyday operation and devising practical techniques suitable to capture the success in everyday operations.

The experience of this method applied this year at plant B has also given support to the framework described in chapter 5, where we translate our experiences with capturing success in a more general approach that can be useful to capture success at the plant during normal operation.

In the next step, next year study, we start from the idea of having a set of success episodes (a collection of TPSs) and analysing them in the perspective of learning. One of the first activities is then to develop techniques for assessing the *learning significance* of the success episodes:

- What can be learned (knowledge, attitudes, skills (KAS), specific improvements)?
- Who may benefit from this learning?
- How may learning take place: How to document the lesson(s) or the TPS for promoting learning?

4.3 Results

We have observed tasks that are well-structured at high levels, but with a significant degree of freedom at the operational level. This type of activity is based on the competence of the members of the team, normally associated with long experience, technical expertise but also a good understanding of the context. The importance of a degree of freedom for creating a dynamic workflow, to enhance innovation and stimulate a positive work climate, has been recognised as a key factor for success (Fagerlind Ståhl, 2015). The activities are subject to variability of different kinds and the tasks are often interdependent.

4.3.1 Learning from successes

The actual learning from successes, is not absent at the plant today, several learning processes, based more or less implicitly on successes, are already part of the daily work. However, the learning processes themselves were not the object of the actual field observations.

In the above-mentioned context the dissemination of competence (sometimes simply labelled "know-how"), as the process of preserving of competences is - quite naturally - assigned to the expert-apprentice working side by side. This is a prevailing organizational learning process that we have observed. In some cases, the dynamic interaction between expert-apprentice results in the latter suggesting improvements to the task at hand.

A process oriented to increasing the operative competence is to share experiences - whether stemming from failure or success - during meetings and forums (systemic) and through informal talking with colleagues (story-telling). The employees consider this process, the oral transmission of direct experience, very effective, and the openness characterizing the environment is a key-supporting factor. Besides the oral transmissions, findings and lessons learnt are documented. After each job a feedback report sheet is compiled with relevant technical issues and archived. The archive is located in the centre of a room at the centre of an area at the workshop offices, physically at an operative crossroad, making feedback reports easily accessible. During the field observations, several people have been consulting these archives.

Essentially the experience sharing concerns technical issues and the main scope is confined to the team working at the same system, and to people having the same role and common background.

4.3.2 Workers perception of success, and sharing of lessons learned

From interviews emerges that success in an activity is perceived as reaching the goals of the task, within the constraint of time and safety. Detailed risk assessment is performed on the place and eventual conflicts are often managed on-the spot, Human Performance tools constitute the framework for this behaviour.

The perception of success, or having 'performed well', is primarily based on the feeling of "having done a good job"- this is essentially related to personal satisfaction and thus rarely leads to sharing a lesson learned - and occasionally on the positive feedback from the supervisor. In this second case a learning phase is more likely to follow. This may suggest that for an effective utilization of learning from successes, some intervention from management, or the like, may be of key significance for learning.

From the interviews emerged also a form of learning from implicit success, related to a development of practice quickly shared inside the group and communicated to the newcomers. Worth of note is the creation of a very specific vocabulary, associating easy-to-remember names to particular pieces of equipment or tools, making the communication more precise and efficient. Having found an effective term for indicating an object is a success, not explicitly recognised as such nor analysed, but readily transmitted. This case the spreading of the name is also an indication on how useful the new name is. Tool invention, adaptation of tools for performing a particular job in specific condition is another type of success recognised, an outcome of a task, not related to the goal, but helpful in the future performance of the task. The success is not analysed, nor the factors leading to it are considered, but the outcome is put directly 'in use'. It seems that 'success' is definitely noted when it has a clear an immediate re-use, probably less noted when the implication are not so obvious, and it could be that factors behind successful adaptation are actually often overlooked. This lack of attention can be seen as a weakness in the last link of the cycle of design, implementation and evaluation of the actual effectiveness of measures to facilitate successful behaviour, such as Human Performance tools.

Noting anomalies, detecting hazardous deviances is also considered a success. It seems that this is recognised and easily communicated when it is related to a technical issues (however probably without further analysis of the factors behind the detection itself). Notice of human or organisational deviances may occur too, and those are managed, but detection and communication of this type of deviances is not so much considered as a successful act, thus not worth further considerations.

Other success stories that can be developed outside a specific task performance were not in the scope of the study at plant B.

A last note should be put on the positive attitude. Having introduced the theme of the study's observations and interviews, that is 'learning from success', generally had a good impact on the subjects, they were motivated to explain us technical aspects, show us their way of working, with a certain proud. Those attitudes will be deepened next year introducing aspects from Positive Psychology (see e.g. Seligman & Csikszentmihalyi, 2000).

4.3.3 Observing adaptations and success assessment

Observing adaptation requires very often a profound understanding of the task, thus a deeper understanding of the task were achieved by follow-up interviews with the task performers. Adaptation episodes were numerous. Local practices (identified as learned adaptations) were often found as a background support for good results. Some of these successes were due to embedded practises related to systemic use of Human Performance Tools (see e.g. Oedewald et al., 2014).

The theory section (chapter 2) supported the definition of a set of criteria guiding the success assessment. With those criteria, summarised in the method applied during the analysis of TPS's, it was possible to extract critical aspects associated with positive outcomes from a task. The observed tasks were then crossed-analysed with information from the interviews; hence a set of sub-tasks (TPSs) could be labelled successful because of a positive outcome - now or later. During the analysis of the task observations, the pre-developed method for capturing successes underwent a strong development.

5 Principles for capturing successes

In this chapter we present a preliminary version of the principles for capturing successes for learning and development purposes. This framework is based on the insights from our theoretical review (see chapter 2) and the findings from case studies (see chapters 3 and 4). In this phase of the LESUN project, the framework serves mainly as a starting point for the further developments that will be done next year. These developments include refining and validating the framework in relation to the opportunities available at nuclear power plants and to currently applied operating experience practices. Overview of the framework structure is illustrated in Figure 10.

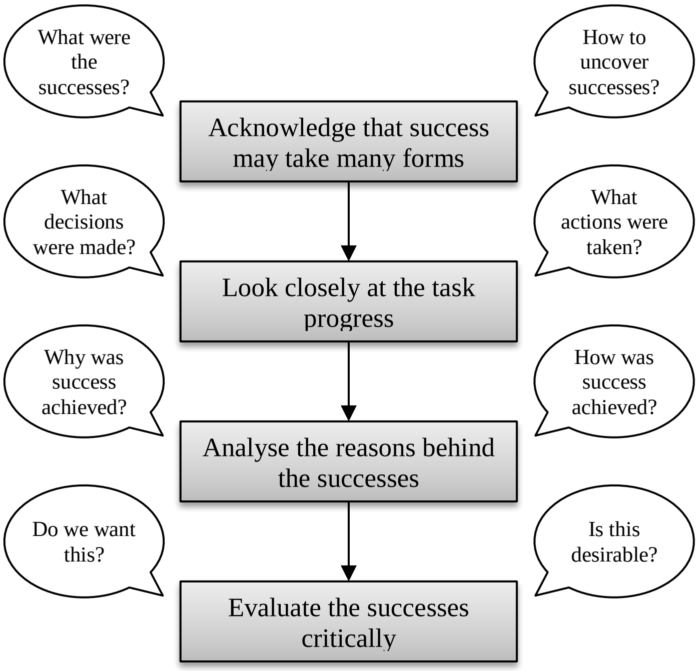

Figure 10. Overview of the preliminary framework for capturing successes

5.1 Acknowledge that success may take many forms

Success is not merely a simple "non-failure", but rather a complicated and multidimensional phenomenon that can manifest itself in many different ways. Acknowledging the complexity of success and attempting to approach it from multiple perspectives may provide better opportunities for learning.

A basic approach to success is to relate it to expectancies and goal-setting, which also brings out the normal and non-normal qualities of success (Figure 11). In this case, success can be seen as something that matches, exceeds or returns the system to a desired level of performance when judged against some relevant performance indicators.

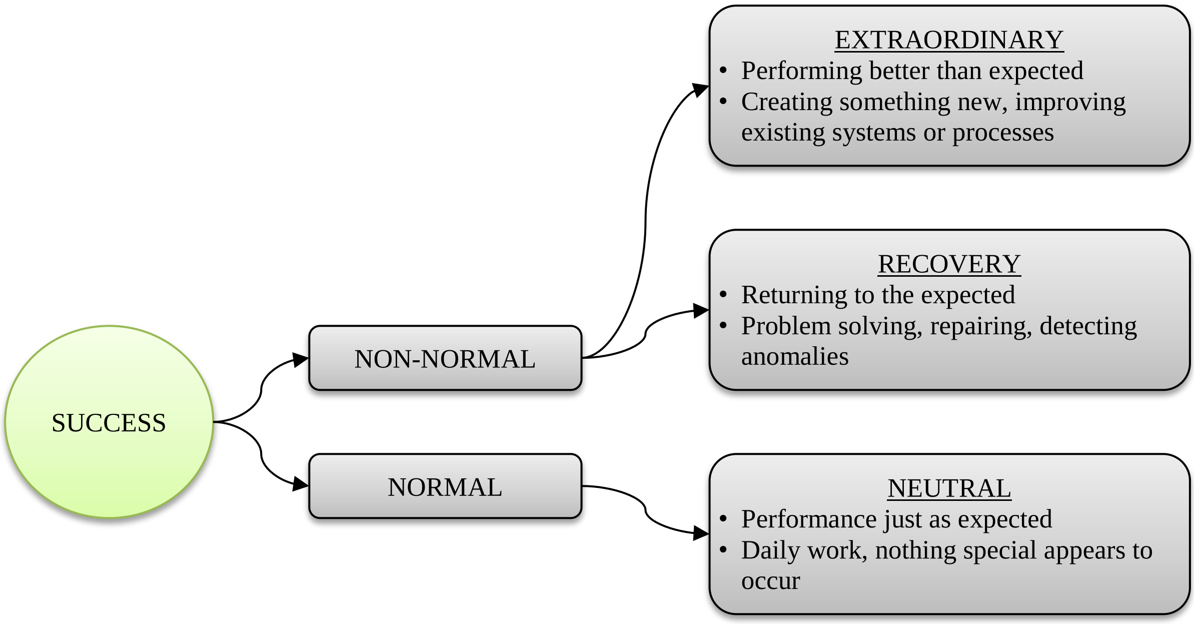

Figure 11. Success can be normal or non-normal

Some examples of relevant metrics against which outcomes can be assessed to identify success in nuclear power plant activities:

- *Process metrics*: carrying out the job as required by e.g. the regulator, company policies, plans and instructions, good safety culture practices
- *Project management metrics*: time spent, budget, scope (i.e. meeting predetermined specifications)
- *Product metrics*: meeting the clients' or end users' requirements
- *Organizational metrics*: creating benefit (e.g. financial, technological, social, structural) for the organization
- *Preparing for the future*: e.g. creating preconditions for future successes; improving work conditions, engaging in proactive initiatives
- *"Lagging"-type safety indicators*
    - Plant safety related: e.g. INES events, License Event Reports, Safety system unavailability, rework
    - Occupational safety related: e.g. injuries, lost days of work
    - Radiation safety related: e.g. annual collective dose
- *"Leading"-type safety indicators*: e.g. the ability to identify, anticipate and remove latent and other unsafe conditions; the ability to respond to expected and unexpected situations; maintaining and developing good safety culture

To further elaborate the assessment of successes, additional factors need to be considered when attempting to construct an extensive understanding of success in operational situations. Some relevant factors are summarized in Table 7.

Table 7. Other things to consider when assessing success

Label	Description	Examples of things to inquire
Multiplicity of stakeholders	Success is perceived by multiple stakeholders (e.g. shop-floor workers, supervisors, departments, licensee, regulator, government, nuclear industry in general), each of which have their own unique viewpoint and objectives for the operations	• Who defines what is to be accomplished? • Who has defined the requirements for a successful task? • Who sets or creates the opportunities for successful performance? • Who benefited from the activity?
Multiplicity of objectives and expectations	Success is defined by multiple objectives and expectations, some of which may be conflicting and may need trade-off management	• What were the objectives of the task? • Were there goal conflicts? • How were the goal conflicts handled? • Who solved the goal conflicts? • Are there existing structures that are meant to manage trade-offs?
Temporality	The extent of success may change over time by means of, e.g. changes to success criteria; change to availability of metrics; or change of stakeholders	• Was the perception of task success changed during or after its completion? • What criteria were used to assess successfulness before, during and after the task? • Who assessed the successfulness of the task in its different life cycle phases?
Feedback and communication	What is perceived as success is transferred via different forms of communication and feedback such as implicit and explicit, written and verbal	• How are successes or desirable operations communicated in the organization? • What formal or written documents are there which describe or define success? • How does informal or tacit knowledge affect what is defined success? • How do supervisors or other agents who evaluate successfulness give feedback to shop-floor workers?
Situation-dependence	What is perceived success is dependent of situation and the demands of the context	• Was the situation routine or exceptional in some way? • Was the situation particularly demanding or easy? • Were there unexpected aspects in the situation? • Did the situation change during the task?
Social construction	Some aspects of success are to some extent subjective, e.g. individual experiences, biases, group norms and culture may affect what is perceived successful	• How do individuals or groups interpret the situations and successes? Are there differences between them? • Are written documents interpreted differently by different people or groups?
Systemic interactions and complexity	The sociotechnical complexity of a nuclear power plant complicates the assessment of success and creates unexpected outcomes	• Did the operation of one actor affect the operation of another actor? • How do the various actors coordinate and communicate? • Did unforeseen processes or outcomes emerge during the task?

Finally, it is important to acknowledge that unlike failures, successes are often covert or not apparent and don't tend to attract spontaneous attention. This means that *in order to uncover the successes and learn from them, one needs to be open and sensitive to finding successes*. In some cases this may require extra resources or active effort. Taking an active role in investigating the contributors to successful operations is one of the prerequisites for learning from success. Nevertheless, *it is imperative to keep in mind that searching for successes must not obstruct learning from failures – a safety-critical organisation mustn't become preoccupied or complacent with its own past successes. Successes are just an additional source of information that should be used in conjunction with information from failures.*

5.2 Look closely at the task progress

When a notable success episode (e.g. extraordinary performance or recovery) has taken place during task execution, looking closely at how the task progressed may provide clues regarding how the success was achieved and what could be learned from it. This process may involve asking the following questions:

"What decisions were made?"
"What actions were taken?"
"What initiated the decisions or actions?"

Figure 12 illustrates what processes could be analysed in a successful recovery situation. *Understanding how these processes were initiated and carried out during the recovery may provide useful information regarding what was actually done to achieve the success*. Similar approach can be taken to analyse performances where something more or better than expected was achieved.

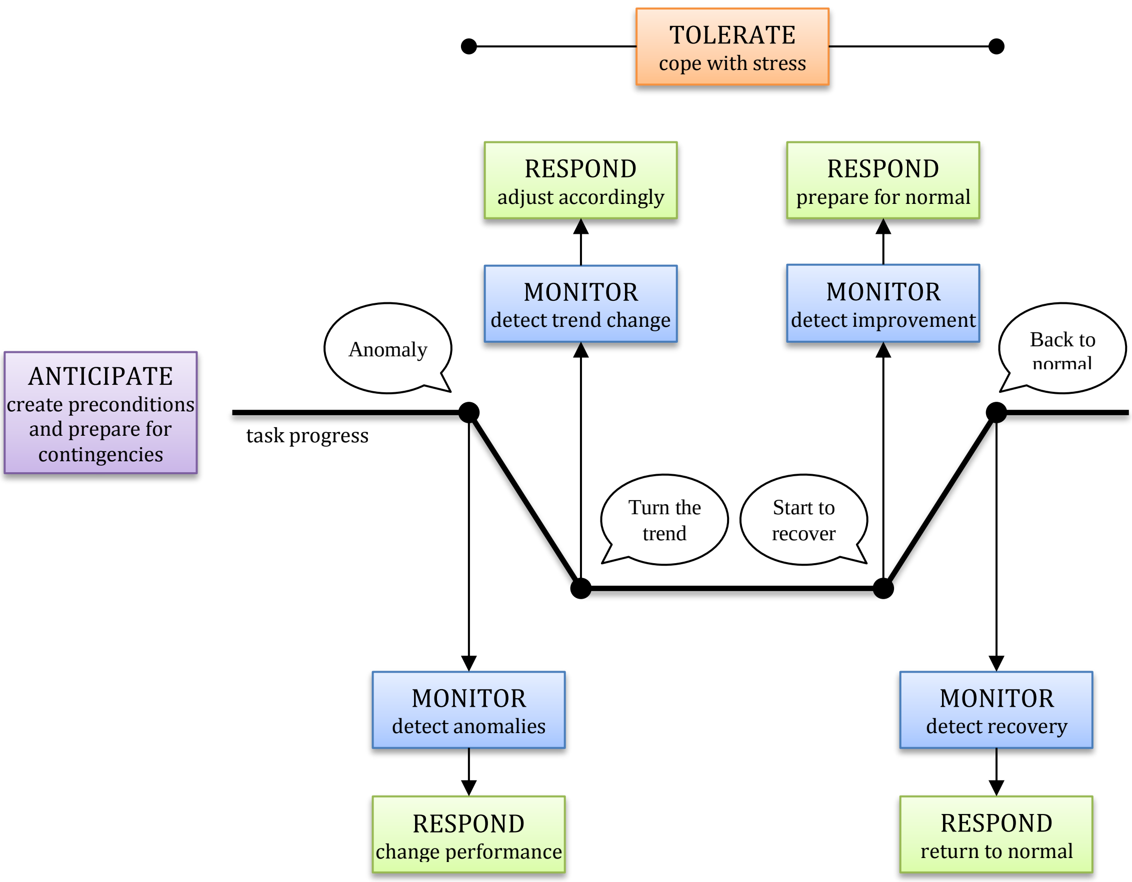

Figure 12. Example illustration of task progress in a recovery situation. The coloured boxes are labelled after the types of adaptive performance as discussed in chapter 2.1. Each of the coloured boxes represents a process that can contain useful information for understanding task progress.

In addition to situations where disruptive changes occurred (i.e. non-normal), *normal performance is also a potential source for valuable lessons*. Quite often this source is ignored because it appears mundane and uninteresting. However, contributory factors and continuous performance variability affect normal activities too (e.g. Hollnagel, 2013), they just don't result in anything unexpected – recognizing them would provide useful information for learning purposes (see illustration in Figure 13).

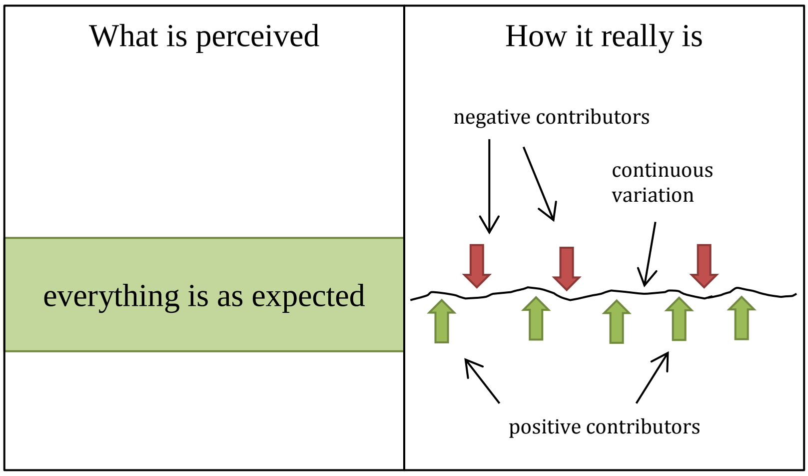

Figure 13. Illustration of the hidden processes behind "normal performance"

5.3 Analyse the reasons behind the successes

Merely identifying and collecting successes is not sufficient for effective learning. It is necessary to understand what the reasons behind the successes were. One approach to such analysis is to *begin a deliberate analysis of what constituted success or what contributed to success*. Essentially, it should be encouraged to ask questions such as:

"Why was success achieved?"
"How was the recovery made possible?"
"What enabled conceiving a useful idea?"
"How was something anticipated?"

In task-based work, the following processes can be considered some of the most important constituents of success:

- *Formal procedures:* e.g. instructions, checklists, regulations, rules, organisation-enforced practices, training and qualification (competence)
- *Informal practices:* e.g. tricks-of-the-trade, local good practices, tacitly embedded knowledge
- *Adaptive performance:* e.g. anticipating future developments or requirements, responding to unexpected events, coping with disturbances, being able to understand and read the context and environment

Putting effort into understanding how the interplay of the abovementioned constituents helped create success may reveal how the success was achieved. In a mature and highly professional organisation such as a nuclear power plant, *it can be expected that all of the above constituents can be found in a given task* in one form or another.

In addition, there are a variety of contributing factors that help achieving success. The following list proposes some of the most prevalent ones:

- *Organisational factors:* e.g. well-established practices, availability of resources and personnel, intra-organisational communication
- *Group processes:* e.g. team-spirit, group climate, collaboration
- *Performer characteristics:* e.g. professional pride, sense of responsibility, extra-role behaviour
- *Technological factors:* e.g. ergonomics, quality of tools

Something to be kept in mind is that on a general level these factors line up quite well with many established analysis methods such as event or accident investigation techniques and safety culture evaluation models. *Utilizing such methods to discover success processes in a particular situation may be an effective and practical way to carry out success analyses in practice.*

5.4 Evaluate the successes critically

All activities that lead to a successful outcome are not necessarily generalizable or desirable. The final step of success analysis should be to establish, whether the organisation wishes to embrace the activity that led to the success or not. *This phase is particularly important in order to avoid reinforcing or creating unwanted processes* such as risky habits or organisational drift, which are undesirable in safety-critical organisations. Learning from successes should lead to future successes rather than future failures. This requires critical evaluation of *what* the successes were and *how* the successes were achieved. An illustration of a general flow of evaluating successful processes and outcomes is presented in Figure 14.

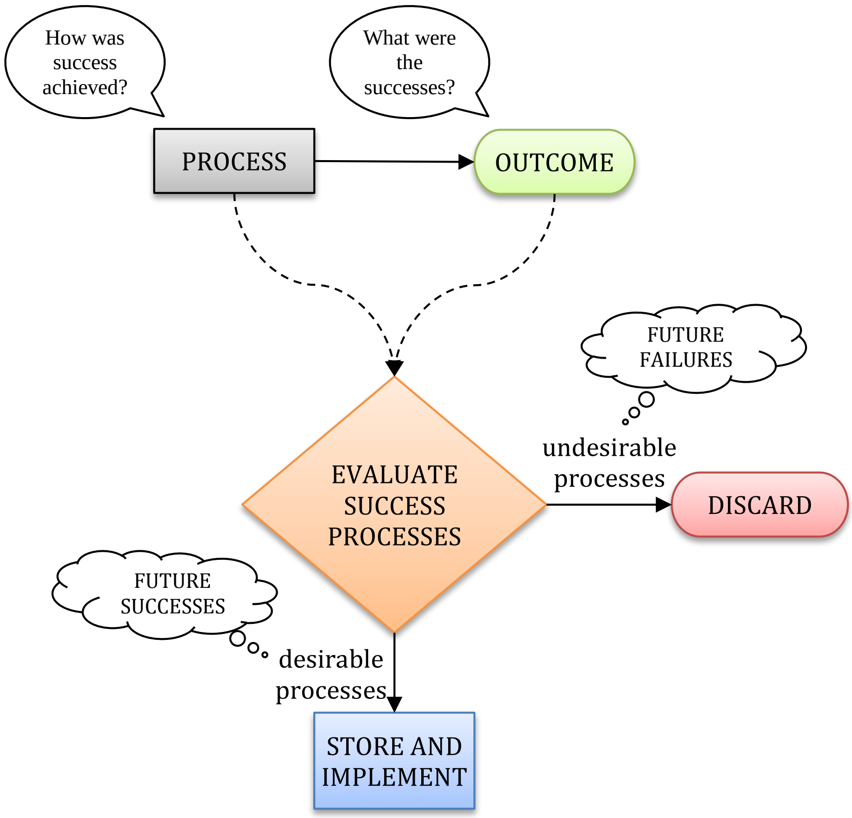

Figure 14. General flow of critical evaluation of successes for learning purposes

Evaluating the successes critically may pose a challenging task. A potential approach would be to apply the insights from various systemic safety or organisational models to distinguish what processes most probably lead to desirable future outcomes. It is also to be expected that as the environment changes, so does the desirability of existing processes: same approaches can't be applied under all conditions. This means that an absolute certainty of the desirability of these processes becomes unattainable – therefore, *the organisation must be constantly mindful and willing to re-evaluate any currently applied practices and unlearn those that have become obsolete*.

6 Conclusions

In this report we focused on addressing the first two research questions of the LESUN study:

1) How to learn from successes? What kinds of theoretical models and practical concepts can be found from non-nuclear application areas?
2) What are the criteria for identifying successful performance adaptations?

To address these two research questions, we first carried out a literature review to establish a sound theoretical basis for our empirical studies and to provide theoretical insight to the concepts that we utilize in this study. The literature review focused first on identifying what is known about adaptive performance; secondly, we reviewed various models and theories that concern success in both non-safety-critical organisations and safety-critical organisations; thirdly, we reviewed literature on the concept of organisational learning; finally we examined the special characteristics of learning processes that relate to successful experiences as opposed to failure experiences. The empirical part of our study consisted of two case studies at nuclear power plants. In the case studies we first attempted to identify what kinds of practices the organisations apply in terms of learning from successes. Second, we collected data from various sources, including event reports, field observations and interviews, to identify what kinds of successful actions and decisions take place in maintenance activities. These successes were then discussed both among the researchers and also with the maintenance personnel to pinpoint the relevant successes and to identify the potential lessons from them. Finally, based on the insights from the theoretical and empirical work, we created a preliminary version of a framework for capturing successes in operational context.

We found in our literature review that success is a somewhat understudied and undeveloped concept in safety-critical context. Success appears to be most extensively discussed in project management literature that also provides multiple success analysis frameworks and insights to how success can be approached. This literature suggests that success is a complex and multidimensional phenomenon; reducing success down to a mere "non-failure" may mean that many important and potentially informative aspects to success would be overlooked. To elaborate on the basic definition of success in task-oriented activity, we recognized three main types of successful situations: normal successes where expectations are met, extraordinary successes where expectations are exceeded and recovery situations during which return to expectations takes place.

In our case studies we attempted to find ways to identify all three main types of successes by means of a diverse selection of data collection methods. For example, document analysis of event reports provided information of how recoveries took place; field observations of activities at the power plants provided us the opportunity to witness normal operations. Furthermore, potentially extraordinary successes were discovered with all of the methods used, but especially in interviews with plant personnel.

We noticed that in contexts where a failure had taken place (i.e. when discussing event reports), it is often somewhat difficult to find the successes (e.g. recoveries), because the interviewees tended to focus on the failures instead. This is in line with what we found in our theoretical review: failures tend to attract more attention that successes. This can be seen as a desirable trait in a safety-critical organisation; however, it may also mean that some useful learning opportunities may be missed. When we prompted the interviewees to also discuss the successes and tried to extract useful lessons from these successes, we did find some factors that may have contributed to the successful recovery. This included, for example, intra-organisational collaborative efforts, creating new ways of doing things, staying calm in stressful or uncertain situations and understanding systems outside one's immediate responsibility area. However, the event reports themselves were rather lacking in terms of discovering successes due to the fact that they were written in a rather failure-oriented manner. A future development could be to add a short positive section into the event reports – something where those activities would be reviewed that prevented worse failures and enabled recovery.

We also attempted to identify "normal" performance in our case studies. We found that it is rather challenging to observe and analyse normal performance, despite that we utilized several different types of methods of data collection. It is likely that a profound understanding of the subject matter (e.g. a maintenance task in a nuclear power plant) in combination with deep insight into behavioural sciences may be required to really understand the intricacies of normal behaviour. In practice, it's rare that an individual possesses both of these abilities. For example, as non-experts of nuclear maintenance task, but knowledgeable in behavioural sciences, the researchers found it quite challenging to distinguish normal behaviour from non-normal behaviour, or different types of adaptations from proceduralised activities during normal task execution. Sufficient understanding the task being performed, formal and informal practices that are applied and typical adaptations done during the task would appear to be the requirements of collecting useful data from normal performance. A potential topic for next year's research activities would be to create such methods that would help those that are already experts in subject matter to more easily identify and report potentially useful, but "normal" things that would otherwise get ignored.

Furthermore, we found many extraordinary successes, especially during interviews when we asked the interviewees to recall successful experiences. We found this a potentially useful method for capturing successes and possibly also lessons. Almost every interviewee could easily think back and find episodes they considered successful in some way. The examples included, for example, improvement of technology, team-spirit, or creating or utilizing good informal practices. However, the generalizability of the lessons learned varied: in some cases the lesson was quite specific or required some abstraction to make it suitable for other departments or situations. The topic of applying specific lessons to improve general activities is something to be further studied in later phases of this project.

Additional things to be considered when identifying success include multiplicity of stakeholders, multiplicity of objectives, time-dependence and systemic aspects. The multiplicity of stakeholders and objectives implies that there are several viewpoints from which an activity can be evaluated from, and that there may be different expectations regarding an activity. For example, stakeholders from different departments or levels of the organisation may have different understanding of what a success is: each focuses primarily on what is relevant from their perspective. In our case studies this manifested itself when different departments made different judgements regarding whether a task had been successful and to what extent. Identifying the possible conflicts may be relevant when capturing successes and when evaluating the generalizability and usefulness of the lessons. In addition, we noticed various time-dependent aspects to success. For example, the indicators available for assessing success may change during the course of the task, or the stakeholders may change; similarly change in environment or the outcome may take place. These are something to consider when collecting information for learning purposes: all aspects of the successfulness of an activity may not be available at all times. This suggests that the lessons learned need to be constantly evaluated and, even if they had previously led to successes, discarded if not applicable anymore. Finally, success in operations has systemic qualities: there may be partial successes, local successes or conflicted successes, but ultimately the system success needs to be ensured. In the empirical studies we found examples of situations where an activity was considered successful from one department's viewpoint, but not from another's, or when there were some aspects of an activity that were successful, but that the overall task failed. These local successes may provide clues to where the strengths of the system may be, however, at the same time the overall functioning of the system is something that needs to be considered when evaluating the lessons so as to avoid making overly general lessons out of specific situations that may not be applicable everywhere.

In the nuclear industry, safety is both a constraint and an expected outcome of all activities. In practice, achieving safety in operations and maintaining or improving the preconditions for safety can be considered a success. We found that safety theories may contribute either directly or indirectly to the understanding of success. A potentially usable approach to defining success from this perspective could be to "invert" the accident models or to examine what is the implication of various safety models to successful activities. For example, complex linear accident models such as the Swiss cheese model could suggest that success takes place when the organisation is able to remove active errors or latent conditions, or maintains an efficient barrier structure. Likewise, non-linear models such as those proposed by Resilience Engineering research tradition would suggest that creating the ability to control and monitor performance variability is a success. In the empirical studies we found many examples of successes that can be related to these approaches. For example, proactively improving the ergonomics of a crane could be related to removing latent conditions in the system, or engaging in extra-role activity such as considering things outside one's own immediate work tasks may be related to improving the monitoring of performance variability, and would therefore be considered successes. Generally, this suggests that existing methods for accident or event analysis could be applied for success analysis, if properly adjusted. Some safety-related methodologies, such as normative safety culture models, readily provide criteria against which activities could be assessed; this can provide another practical way to evaluate successes. Applying these safety models may help judging whether a lesson learned is something that should be embraced by the whole organisation or not.

In order to gain better understanding of the concept of adaptations, we attempted to go beyond what is discussed in the basic literature of Resilience Engineering tradition (i.e. the four resilience cornerstones) and reviewed a variety of essential papers regarding adaptive performance at work. This revealed a variety of practical manifestations of adaptive performance at work in different domains. We found examples of many types of adaptive performance in our case studies that corresponded with the findings of the theoretical review. It appeared that adaptive performance was quite important constituent to the successes of some of the activities – this was especially obvious in situations that were complex or dynamic. This suggests that the preliminary list of adaptive performance behaviours or abilities that we identified from the literature is quite well applicable to nuclear domain and could be, with appropriate adjustments, a potentially useful starting point for the identification and closer analysis of successful performance adaptations – and ultimately a source of lessons.

We also discussed what the special characteristics of learning from success are and how learning from success differs from learning from failures. In the literature review we found that failures are commonly more salient and attract more attention; furthermore, it seems negative events in general have a certain tendency to create more interest that successes. This may suggest that attempting to intentionally learn from successes may be counter-intuitive or difficult, which may affect how the learning processes can be implemented. This inclination is probably further amplified by nuclear regulatory requirements and company policies that tend to put less effort to understanding success, or ignore successes completely. However, even though the nuclear industry may appear, as do many other safety-critical organisations, preoccupied with failures and successes are not a centre of focus, we observed in both of our case studies that the power plant personnel was rather intrigued by the concept of learning from successes. This came up both during explicit inquiry when we asked the personnel how they feel about harnessing successful experiences for learning purposes, and the personnel also spontaneously showed fascination with the topic when we mentioned our research topic. The interviewees were also able to explicate the concept of success and identify various types of successes when prompted. Collectively, the interviewees brought up a variety of success conceptualisations, not unlike the ones we identified in our theoretical review.

We found that many existing practices where successful experiences are reviewed (e.g. post-job reviews, feedback meetings and informal discussions) were already in place in the case study at the power plants. The existing practices, however, didn't seem to be particularly focused on actual learning and reflecting activities, but rather on bringing up successes or agreeing on them. Learning from successes didn't therefore appear to be very systematic, which, however, doesn't necessarily mean learning doesn't take place, but rather that it is most likely unstructured. As a whole this suggests that the plants already have certain prerequisites in place for learning from successes and that there is motivation for this, but there appears to be a need for concrete methods that would enable constructive learning from successes. More systematic reflection of successes and the subsequent learning activities are also desirable considering that if learning is allowed to continue in a self-organised or informal manner, it could cause a risk of undesirable outcomes such as organisational drift or the formation of bad habits. A critical evaluation of lessons learned is especially important when it comes to learning from successes; therefore an explicit scrutiny is important.

One of the common ways to collect and share knowledge is to codify it to organisational structures (e.g. instructions, work practices, etc.), and this is where those organisational units that are responsible for operating experience can be active in terms of learning from successes. However, due to the great amount of successes, especially those related to normal activities, data overload may become an issue when collecting information for learning purposes. This is an issue something that doesn't seem to have been addressed in Safety-II literature. In our empirical studies we found that in addition to the explicit and codified sources of information, tacit or informal knowledge had significant relevance to successfully carrying out the operations. This may suggest that the organisation naturally embeds the information from successful experiences into tacit structures such as individual or group knowledge, tricks-of-the-trade or culture. Tacit and informal information storage, however, exposes knowledge to certain dangers. Our theoretical review and empirical studies brought up the following examples: tacit information is not as persistent as explicit and there is a threat of losing a lot of knowledge as result of individual turnover; in addition, self-organised learning may result in organisational or practical drift – a gradual change of activities towards more risky. Overall this suggests that especially when considering lessons learned from successes, it is important to put effort into understanding the tacit aspect of learning.

An interesting finding that was observed in both of our case studies was that successes appeared to be related to social phenomena such as bonding, team-spirit, work motivation, good interpersonal relations. This seemed to be both a contributory factor to success and an outcome of a successful task. For example, after successfully completing demanding work tasks, the team might become closer and create a commonly shared “success story”, which would further improve their team-spirit and work motivation in future tasks. Similarly, we found that event investigations may be socially difficult processes which require interpersonal skills to maintain good overall culture in the organisation. When attempting to bring the findings from LESUN study to practice, these social phenomena may be of interest and something to consider. Further inquiry to concepts such as positive psychology may provide valuable insights when attempting to collect or implement knowledge from successful experiences during later phases of LESUN project.

Future objectives of this project aim to bring our findings closer to practical operating experience work at nuclear power plants. This may involve, for example, validating and discussing our findings and assumptions with operating experience personnel. In addition, examining the methods applied at the plants to collect and analyse information, and aligning the success capturing methodology developed in LESUN project to commonplace operating experience practices could be beneficial to provide usable tools for real-world work.

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Appendix 1: Plant A interview guide

General

Background questions

1) Who are you and what is your job in Plant A?
    a. Position in the organisation
    b. Current job tasks
2) What do you find challenging in your work?

Perception of success

3) How does one know when one has succeeded in a task? What criteria are there for “success”?
    a. Who or what defines these criteria of success?
    b. Are there any contradictions or ambiguities regarding the successfulness of a task?
4) Do you or your subordinates have any personal or subjective criteria for “success”?
5) Does success always manifest itself immediately or can it also manifest later? How?

Perception of learning

6) What are the most important means of learning among the personnel in your area of work? How about regarding sharing of lessons learned?
7) Are successes discussed from learning point of view?

Event report/field observations

Backgrounds of the situation

8) Describe the situation/task briefly
    a. What was your role in the situation?
9) [*FOR FIELD OBSERVATIONS ONLY*] What were the most critical phases of the task – those in which it is especially important to succeed in?

Successes and lessons

10) Where did you succeed and what were the successes like?
11) What decisions or actions led to the successes?
12) [*FOR FIELD OBSERVATIONS ONLY*] What unusual or unexpected took place during the task?
13) What could be learned from these successes? Who could learn? Are these lessons shared and how?

Appendix 2: Plant B data collection guide

This document constitutes a guide to collect data at a NPP enabling us to *capture successful performance adaptations*. Based on observation of activities and interview opportunities this guideline helps analysts to capture data to be used for an analysis of success and factors supporting them.

Approach to data collection used at the plant B:

1) Prior to observations: Obtain background data and carry out a task analysis (level of detail depending on the situation), if possible.
2) Look for / select for opportunities to observe activities where adaptations are frequent; Plan interviews with roles that are daily in contact with adaptations.
3) For carrying out the observation of a task
    - When possible: observe the Pre-Job Briefing/Preparation of the task (Part I below)
    - Observe task execution (one or more task performer, depending on what is possible) (Part II below)
    - When applies: Observe the Post-Job Debriefing, if possible (Part III, below)
    - When possible: Interview the personnel after they have completed their tasks (Part IV, below)
4) For interviews
    - Use the points in Part V below

Part I: Observe: PJB/Preparation

The goal of this part of the data collection process is to obtain a detailed description of the task performance process to be observed:

Describe:

- People (roles) involved
- Activities performed, timing.
- Note everything that has to be with Goals and Expectations (criteria)
- If possible, document the associated procedures, tools, etc.

If possible, get a copy of the filled-in PJB schema following the PJB meetings.

Part II: Observe: Task execution

Use the description resulting from Part I as basis, if it exists.

Document the task performance process, as it unfolds, keeping an open perspective

- People (with their roles and positions) involved
- Activities performed, timing.
- Everything related to performance assessments like delays, re-planning, unexpected conditions, deviances, etc. (e.g. success or failure not necessarily using these words) expressed by the persons involved in the activity
- Challenges they encounter during task performance
- Factors that promote task performance – including chance factors.
- Errors occurred – and if they are corrected
- Procedures followed, communications and communications tools, etc.
- Successes you notice – even if the task performers may not have similar conception.

Part III: Observe: PJD/Debriefing
Observing PJD

- Ask if it is possible to tape record (consent form)
- Note background information: Who takes part (roles – including roles during the task performance process if relevant); How long does the meeting take, etc.
- Write as verbatim as possible (preferably tape record) the conversation during the PJD.
- If allowed to ask questions: Could you please describe in a little more details what happened here (periods where successes unfolded).

Part IV: Semi-structured Interviews related to observation
Ask if it is possible to tape record and administer consent form.

Background [BRIEFLY]

- Who are you and what is your job at this Plant? (Position, Current tasks, Previous tasks)
- What is your education and job background?
- What do you find challenging in your work?

Risk and Success according to you

- Ask the interviewee how he/she perceives successful task performance in general (cover issues of procedure adherence and adaptation, not necessarily using these words)
- What factors are important for teams/your team/role to be successful in the task we've just observed?
- What are the major risk factors associated with the task – safety, efficiency
- Did you think of/prepare for any alternative strategies, should something go wrong?

The task performed

- What were your expectations to the (this particular) task performance process (before it started)?
- Could you please describe how you solved the task? (What did you do first, etc.)
- Ask follow-up questions related to team/collaboration, situation awareness, coordination, etc. and organizational factors whenever it seems relevant.

The success

- During task performance process, did something unexpected/unplanned (surprising) happen?
    - Was it a known condition that normally any operator knows how to face? (Existing rules apply directly)
    - Was this event requiring an on-fly new solution?
    - Why was it necessary to approach the event with a not off-the-shelf solution? (Lack of procedures, not a perfect match with the procedures, etc.)
- Looking at the [unexpected] event/situation you handled well [successfully adapted performance]:

- When you performed this same task earlier, did you have to adapt you performance as well?
- Could you describe the differences and similarities between the earlier times, and the present task performance?
- What are the preconditions for the solution you developed this time to be successful?
- In what situation might this solution work well – and in what situations (if any) might it not?
- What enabled this good solution to be developed?
- (How did colleague, training, leaders, etc. contribute to the solution?)
- If some elements in the situation had been different, could it have gone wrong?
- Do you think there were/might be any side effects (positive/negative) of the good solution you developed – now or across time

Part V: Semi-structured Interview not related to an observed task
Background [BRIEFLY]

- Who are you and what do you do at this Plant? (Position, Current tasks, Previous tasks)
- What is your education and job background?
- What do you find challenging in your work?

Risk and Success according to you

- Ask the interviewee how he/she perceives successful task performance in general (cover issues of procedure adherence and adaptation, not necessarily using these words)
- What factors are important for teams/your team/role to be successful in the task we've just observed?
- What are the major risk factors associated with the task – safety, efficiency

Part VI – annotations to raw data
Last step for preparing the raw data to analysis:

- Collect the examples on successful performance adaptation you've just observed during task performance – both successes noticed by the task performers and successes only you noticed.

  For each success:
  - What was/could be the reason for the success (chance factors, skill factors, etc.)
  - What may others learn from the success (why is it important?)
- Attempt to answer to: What would be useful principles for capturing this type of successes?

Appendix 3: Plant B guidelines for identifying success episodes

The method used for the study at plant B (see chapter 4.2), at Step 2 foresees the splitting of an observed task (Structured Task Description) in simpler units, or episodes (Task-Performance Sequence, TPS), that can be considered successful. To perform this analysis we used in the background the following template, a table to be filled for describing the episodes, based on a set of questions helping to evaluate the episode (TPS).

QUESTIONS	**Answers**	**Comments**
***TPS* Judged to be successful**		
Overall task:		
Time:		
Description of TPS:		
Characterise the extent to which the TPS describes a routine occurrence – unexpected occurrence.		
Significance of the success in terms of safety and/or efficiency?		
Criteria for success assessment of the TPS		
Account for the subjective/domain specific criteria for assessing the TPS as successful.		
Your overall/generic criterion/criteria for assessing the TPS as "successful"		
Was this judgement based on Identification, Understanding, Decision, Implementation and/or Outcome?		
Was the outcome as expected – innovative?		
Did the task performer(s) conceive performance to be a success – and why?		
Applicable standard criteria:		
Framework conditions for the classifications		
Organisational position: Judgement is based on information from what organizational position (e.g. task performer)		
Temporal: Judgement is based on information obtained at what time in relation to the TPS (e.g. right after)		
Contextual elements contributing to the success (What would be needed to reproduce the success in another group/organisation)		
Success due to adherence to procedures - adaptations		
Organisational factors		
Technological factors		
Performer characteristics		
Chance factors		
Variations (now-then)		
What are the differences and similarities between the two task-performance processes?		
Why did "whatever went wrong then" not happen during the observation?		

Bibliographic Data Sheet	**NKS-354**
Title	Learning from Successes in Nuclear Power Plant Operation - Intermediate Report from the NKS-R LESUN
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Abstract max. 2000 characters	Learning from experience is essential to achieve safe and efficient operations at nuclear power plants. In the nuclear industry, licensees are required to collect lessons from unwanted events in order to prevent the recurrence of similar events. This implies focus on learning from failures, which may limit the opportunities of the organisation to develop. Modern safety theories such as Resilience Engineering suggest that also using successes as sources for learning may be beneficial. In this project we elaborate the concept of success in nuclear industry and how it can be utilized for learning purposes. The scope of this intermediate report is to provide insights to how successful actions and decisions can be captured and how learning processes from successes and failures differ from each other. To achieve this we carried out an extensive literature review and two case studies in nuclear power plants. We found that success is a complex and multidimensional concept that can take many forms. We identified three broad

categories of success: normal performances, extraordinary performances and recoveries. We also observed that success can have properties such as time and situation-dependence and that it relates to the objective or subjective expectations of multiple stakeholders. Based on our findings we formulated a preliminary framework for capturing successes. We propose that this framework can be useful to identify successful situations for learning purposes.

We also found that successes are often less salient and less likely to trigger intentional learning processes than failures. Regardless, we found in our empirical studies that there was clear interest in successes at the power plants: existing methods, albeit not very refined, were already in place that could be utilized to learn from successes more systematically. Further developing these activities is also important in order to avoid unwanted side-products of learning from success such as organisational drift or complacency. In addition, because lessons learned from success are often tacit, exploring the possibilities of developing learning that relates to tacit knowledge may be useful. Operating experience activities have a central role in facilitating the development of these learning activities.

Key words: Success, adaptive performance, operating experience, organisational learning, safety, resilience engineering

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