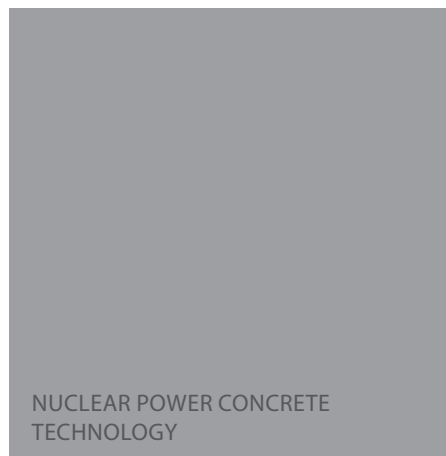
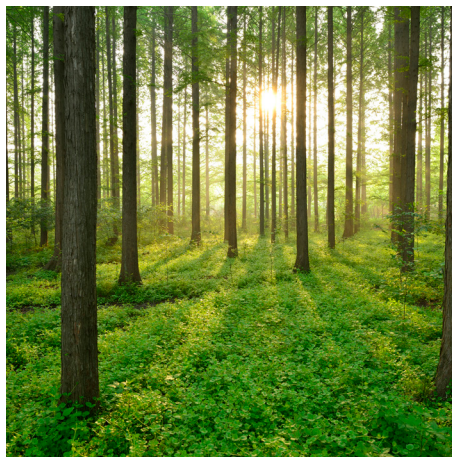
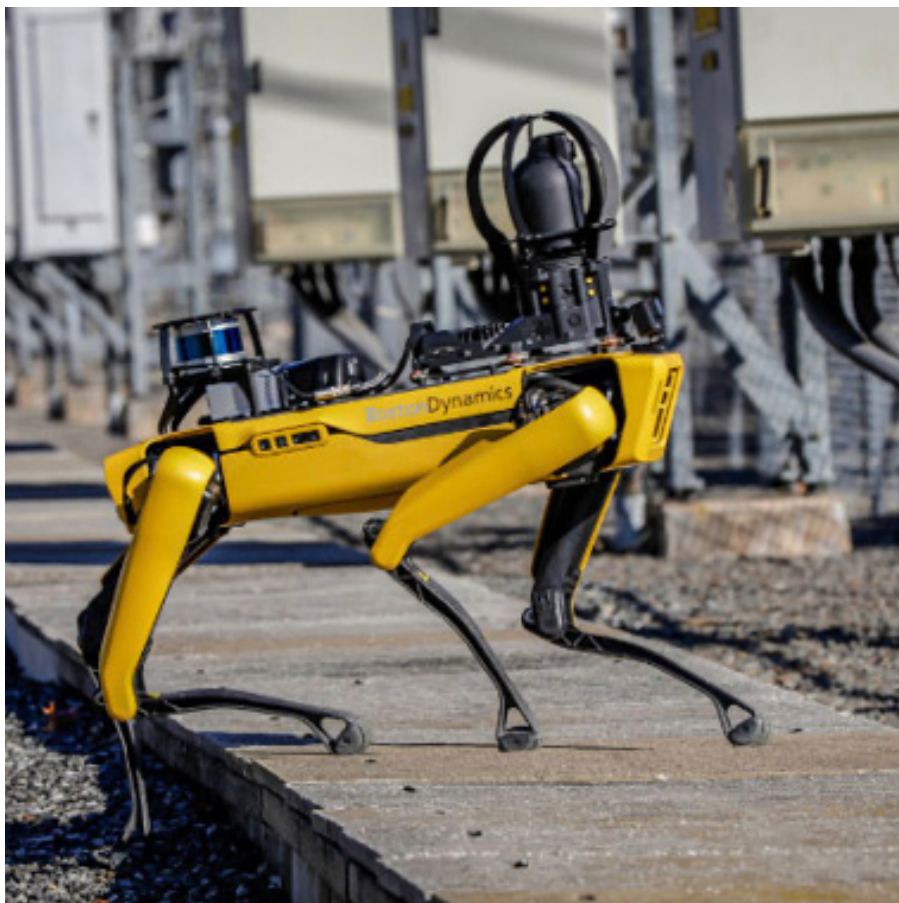
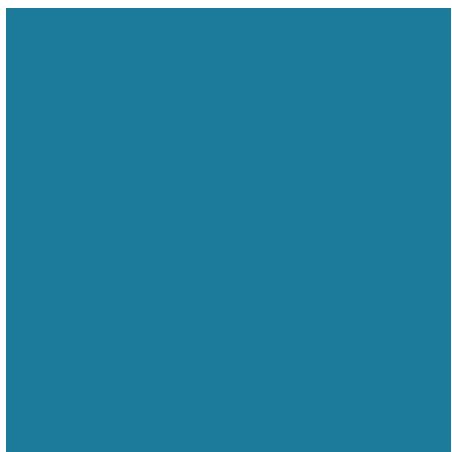


MAKING INSPECTIONS OF CONCRETE STRUCTURES IN NUCLEAR POWERPLANTS MORE EFFICIENT

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NUCLEAR POWER CONCRETE
TECHNOLOGY



Making inspections of concrete structures in nuclear powerplants more efficient

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Förord

Ett av Energiforsks kärnkraftsportföljs syften är att följa med i teknikutvecklingen för att undersöka möjligheter att underlätta och förbättra det arbete som sker inom branschen.

Den snabbt växande digitaliseringen ger nya möjligheter inom många områden, så även besiktningar, inspektioner och analys. Denna studie identifierar och utvärderar digitala metoder och verktyg som kan användas för att underlätta och effektivisera besiktningsprocesser på de nordiska kärnkraftverken.

Studien utfördes av Peter Cvitanovic, Marit Täpp och Finn Midbøe på Rejlers Sverige AB med medel från Energiforsks kärnkraftsportfölj. Portföljen finansieras av Vattenfall, Uniper, Fortum, TVO, Skellefteå Kraft och Karlstads Energi.

Här redovisas resultat och slutsatser från ett projekt inom ett forskningsprogram som drivs av Energiforsk. Det är rapportförfattaren/-författarna som ansvarar för innehållet.

Preface

One mission of the Energiforsk Nuclear portfolio is to follow the developments in the general field of technology, to investigate possibilities to facilitate and simplify the work that is performed in the nuclear business.

The fast developing digitalization brings many new opportunities, for example when it comes to performing inspections and analyses. This study identifies and evaluates digital methods and tools that can be used to facilitate and streamline inspection processes at the Nordic nuclear power plants.

The study was carried out by Peter Cvitanovic, Marit Tåpp and Finn Midbøe at Rejlers Sverige AB. The Energiforsk nuclear portfolio is financed by Vattenfall, Uniper, Fortum, TVO, Skellefteå Kraft and Karlstads Energi.

These are the results and conclusions of a project, which is part of a research programme run by Energiforsk. The author/authors are responsible for the content.

Summary

Visual inspections of concrete constructions in nuclear power plants are performed continuously to verify status and make sure that the established requirements for the constructions are fulfilled. Currently the inspectors make limited use of digital tools and spend a considerable amount of time searching for data and writing reports, compared to the actual inspection time. This report aims to identify and evaluate methods and tools that can be used to simplify and streamline the inspection and documentation processes.

This report describes current inspection and documentation methods and identifies in which manner these might be improved. Identified tools for this purpose are listed and evaluated. They have been classified as primary and secondary solutions, where the former can potentially have a high impact within existing documentation systems and structures, i.e. low hanging fruit, and the latter could be used in specific circumstances or in the long term, when considering replacing the current systems.

A central objective is to simplify the documentation process and rationalise it in order to save time. Faster input could be enabled by reviewing and optimizing the report structure. The aim is to make the inspectors' work simpler, quicker or reduce the workload, freeing up more effective time to make qualified assessments of damages and risks. Today, the inspectors use ordinary pen and paper during the inspection and then re-write the text on a computer when they compile the reports. Time can be saved if the text is written in a digital format at once. This can be achieved for instance by bringing a mobile device, like a tablet, to the inspection site. The inspector can then write directly into the report using a keyboard, or by using a speech dictation device that generates text, or have an appointed secretary do the writing. Also, images can be inserted directly into the report by using the tablet's built-in camera.

The possibility to use drones is also considered as a secondary solution, along with extended use of photo comparison. These techniques can be useful when inspecting places that are difficult to reach or when certain points of damage need to be monitored over time. The techniques are likely to improve the inspections but might require relatively large investments and changes to the daily work and current documentation systems.

Keywords

Inspections, concrete, speech recognition, dictation, report structures, drones, repeat photography.

Besiktningar, betong, diktafon, rapportstruktur, drönare, repeat photography.

Sammanfattning

Okulära besiktningar av betongkonstruktioner utförs kontinuerligt för att kontrollera status och säkerställa att konstruktionerna uppfyller ställda krav. Personalen som utför inspektionerna har för närvarande begränsad tillgång till digitala verktyg och hjälpmedel och tillbringar mycket tid med att förbereda inspektioner och skriva rapporter jämfört med besiktningen som sådan. Syftet med denna rapport är att identifiera och utvärdera metoder och verktyg som kan användas för att underlätta och effektivisera besiktningsprocessen.

Rapporten beskriver hur besiktningar genomförs idag och på vilket sätt besiktningsprocessen skulle kunna förbättras. De verktyg som påträffats listas och utvärderas. Verktøyen har klassificerats som primära och sekundära lösningar, där den förstnämnda kan fungera som processutveckling med hög effekt inom befintliga system, och de senare kan användas vid vissa utvalda tillfällen eller i en framtid då nuvarande system ska uppgraderas.

Ett huvudsakligt mål är att förenkla dokumentationsprocessen och minska den tid som krävs för att skapa rapporter. Besiktningsmannen använder idag penna och papper under besiktningen och skriver sedan om texten på en dator vid skapandet av rapport. Tid kan sparas om texten skrivs digitalt direkt och kan uppnås genom att ta med sig en surfplatta eller bärbar dator under besiktningen, vars inbyggda kameror också kan underlätta processen. Besiktningsmannen kan skriva direkt i rapporten med tangentbord eller genom att använda en diktafon som genererar text, alternativt utse en sekreterare som kan skriva texten. Även rapportstrukturen skulle kunna ses över för att möjliggöra snabbare inmatning.

Möjligheten att använda drönare beaktas också som en sekundär lösning tillsammans med utökad användning av foton för skadejämförelse. Dessa tekniker kan vara användbara vid besiktning av platser som är svåra att nå eller när vissa skador behöver övervakas över tid. Teknikerna kan sannolikt förbättra besiktningarna men kan kräva relativt stora investeringar och förändringar av det dagliga arbetet och de nuvarande dokumentationssystemen.

Table of contents

1	Background	8
2	Method	9
3	Results	10
3.1	Current state analysis	10
3.1.1	Work orders	10
3.1.2	Inspection routines	10
3.1.3	Identifying areas of improvement	12
3.2	Mapping potential solution concepts	13
3.2.1	Primary solutions	14
3.2.2	Secondary solutions	17
3.2.3	Discarded or suboptimal alternatives	20
3.3	Commercially available solutions	23
3.3.1	Speech dictation devices	23
3.3.2	Tablets and laptops	24
3.3.3	Drones	25
3.3.4	Photo comparison / repeat photography	25
3.3.5	Software suites for documenting constructions sites and progress	25
4	Discussion	27
4.1	Suggested solutions	27
4.2	Long term strategy	28
5	Conclusion and recommendation	30
6	Reference list	31

1 Background

Visual inspections are the most frequently performed and simple type of inspections in nuclear power plants. In buildings with hundreds of rooms, like nuclear power plants, they can nonetheless be a monumental task. In a Swedish context, they are conducted in an analogue manner, as the inspectors do not use digital tools for documentation, positioning or orientation. The non-core activities of the inspections, pertaining to documentation and administration, are consequently disproportionately time consuming.

Concrete is a durable material and is used in a range of different applications, such as bridges, hydroelectric dams and nuclear power plants. In order to be able to support large structures of the aforementioned kind, concrete must be resilient to large forces, but also steadfast over time.

Despite its apparent resiliency, concrete is subject to several processes of wear and deterioration over time. Concrete in the context of nuclear power plants is no different – cracks, weathering and other types of damage occurs over time, which can be detected through simple visual inspections. As the great number of concrete constructions in nuclear power plants are critical for the safety and operation of the plants, it is imperative that they are properly and regularly inspected and, if need be, repaired. This is of the utmost importance for concrete constructions and nuclear power plants in general, but perhaps particularly in those that are coming of a certain age: The Swedish nuclear power plants were commissioned in the 1970's and 1980's, and the original design service life for some of these constructions has already been exceeded, making inspections and maintenance all the more important.¹

This report aims to ascertain the way in which inspections of concrete structures in nuclear power plants are conducted today, in which manner they might be improved, and survey available tools and resources with which this could be achieved. Moreover, as the topic of this report is how rationalisation of the documentation process itself can be carried out, rather than the method by which the inspectors work, the focus is on documentation structures and processes.

¹ Hejll, A. *Civil Structural Health Monitoring – Strategies, methods and applications*, 2007, LuTU, cited in Ulriksen P., *Utvärdering av oförstörande provningsmetoder med möjliga tillämpningar inom kärnkrafttekniska betongkonstruktioner*. Elforsk rapport 08:24, p. 45.

2 Method

The purpose of this report is collection and synthesis of information about current conditions in the Swedish nuclear power plants and how certain processes can be improved. In order to achieve this, qualitative methods have been employed. A wide range of information has been required in order to determine current needs, the level of digitalisation in similar operations, as well as what is currently commercially available. The backbone of this study has therefore been comprised of interviews, carried out in a semi-structured manner, questionnaires have also been produced and sent to individuals of interest. Potential solutions, interviewees, other contacts and general information pertaining to the project have been found using the internet and through professional contacts. Experts on certain areas have also been consulted as to give a more complete view of said areas.

3 Results

3.1 CURRENT STATE ANALYSIS

Visual inspections are of interest in this study. The questionnaires and interviews with appropriate personnel show that there are only slight differences between how inspections are carried out in the Swedish nuclear power plants Forsmark, Ringhals and Oskarshamn. The differences are mainly not related to the technique by which the inspections themselves are performed, which is a more universal type of knowledge, but rather to the way the administration and information structures surrounding the inspections are built.

3.1.1 Work orders

The concrete structures are inspected at regular intervals. The intervals differ depending on the functionality and placement, and therefore importance, of the structure itself. For example, a small crack in the wall of a corridor on the periphery of the complex would be less important than the same crack closer to the reactor. As has been mentioned previously, the way in which the data and information pertaining to the inspections is stored and handled varies slightly between the power plants.

When a work order is issued, the assigned inspector(s) retrieves all relevant documentation, e.g. maps, drawings and previous inspection reports, and plans the inspection. Thereafter, one or several time-slots for the inspection are set, and the inspectors are equipped with the necessary equipment (cameras, measuring instruments, the aforementioned documentation, etc.).² The inspectors search the concrete structures visually for damage, e.g. cracks, discolouration or rust, as well as by other methods, such as hammer sounding, a non-destructive method for localising defects and hollowness/cavities in the concrete. The results of the inspection are compiled and documented, then the information is sorted and stored in the documentation system. An analysis is then carried out to determine whether action needs to be taken.³

3.1.2 Inspection routines

When performing an inspection, documentation from the previous inspection is used to examine the damage and assess its current condition and whether it is deteriorating. The technical department is consulted in cases of more extensive damage. After the inspection, documentation is compiled and sent to the facility owner (the technical department) via each facility's documentation system. The documentation is used as a basis for further decisions by the technical and maintenance departments.⁴ It is noteworthy that the maintenance department (Swedish: *Underhållsavdelningen*) is responsible for the inspections.

² Persson, M., Vattenfall. Interview, October 20, 2021.

³ Turesson, J., Vattenfall. Questionnaire, answered in September 2021.

⁴ Turesson, J., Vattenfall. Questionnaire, answered in September 2021.

It is expressed that a lack of continuity is a central concern for the inspections, as it is dependent on the amount of time available for documenting the findings after the inspections. Understaffing and lack of time are therefore two factors which hamper the quality of the documentation.⁵ At the same time, it is important to ensure the quality of the inspections regardless of which inspector is assigned to an inspection, i.e. reducing individual differences. There has been a conscious effort to improve this at some of the power plants by creating clearer and more firm guiding instructions.⁶⁷ It is also noted that the documentation process is often deprioritised. This means that a relatively long time can pass between the inspection and actually writing the report, which in itself decreases the quality and accuracy of the documentation and likely contributes to a slower process of writing the final report. Encapsulating the entirety in the written report by connecting layouts, damage assessments and pictures in one document becomes more difficult as more time passes after the inspection.⁸

The codified instructions which are to be followed during the inspections specify what is to be considered damage and how to assess it. The inspectors are instructed to photograph such damage and the images are to be given a name indicating the building's designation and room number. More pictures are often taken than necessary (e.g. due to them not being of good enough quality), and most often, but not always, all images are saved in the documentation systems.⁹ At one power plant, a form is printed for each room, and all damage is documented and given a numbered assessment based on its size and importance or seriousness. The inspector assesses whether to repair the damage or monitor it until the next inspection, however the power plant does not have any formalised acceptance criteria.

At one of the power plants, inspections are distinguished as being either small or large inspections. Complete and thorough reports and documentation is only required for the larger inspections, whereas only partial reports or shorter comments are prompted for the smaller inspections. This method leads to there being "a lot of knowledge that is not documented". It is expressed that it would be advantageous to only do larger inspections (as is done at the other two facilities), as these give the opportunity for a more thorough methodology. Personnel working at all three facilities report that most damage, e.g. cracks, are repaired as soon as possible after they are discovered, and it is estimated that there are approximately five cracks or other types of damage which are under observation.¹⁰

11 12 13

The total time for an inspection is made up of preparations, the inspection itself and documentation. It is estimated that preparations for the inspections require

⁵ Turesson, J., Vattenfall. Questionnaire, answered in September 2021.

⁶ Persson, M., Vattenfall. Interview, October 20, 2021.

⁷ Brandin, U., Uniper. Interview, September 15, 2021.

⁸ Persson, M., Vattenfall. Interview, October 20, 2021.

⁹ Turesson, J., Vattenfall. Questionnaire, answered in September 2021.

¹⁰ Turesson, J., Vattenfall. Interview, October 5, 2021.

¹¹ Turesson, J., Vattenfall. Questionnaire, answered in September 2021.

¹² Brandin, U., Uniper. Interview, September 15, 2021.

¹³ Persson, M., Vattenfall. Interview, October 20, 2021.

10% of the total time, while the inspection itself and the following documentation and administrative work make up 30% and 60% of the total time, respectively.¹⁴ When the inspectors are out in the field, the results are documented with pen and paper in a form/template. The written text, as well as photos and other material, are manually transferred to a word-document when the inspector has returned to their stationary computer.

3.1.3 Identifying areas of improvement

3.1.3.1 Information and documentation structures

The interview- and questionnaire-based research method has sought to establish a clear picture of the current state of the inspections and what could benefit from being improved. The way the information structures surrounding the inspections are navigated and used has been identified as *a core issue*, and has been touched upon previously and highlighted by inspectors and personnel with insight. This primarily stems from the large time-consumption associated with the documentation of the inspections, estimated to 60 % of the total inspection time.¹⁵ There are hundreds of rooms in each facility, and the task to manually transfer, i.e. simply re-write what has been written by hand to a digital document and link that together with pictures, location descriptions, measurements, assessments, analyses, etc., is an integral part of what is to be addressed in this report. Simplifying, streamlining or partly bypassing the writing process is likely a key measure. The identified areas of improvement are therefore not related to the inspection techniques per se, but rather how the inspections as a whole might become more streamlined, and particularly the documentation-related process.

3.1.3.2 Inspection types, standardisation and harmonisation

The interviews have also found that there are differences between how individual inspectors conduct and document the inspections. Naturally, individual differences are to be expected in a context without a higher degree of automation and digitalisation, as well as where individual skills and personal characteristics affect the results. It is, however, beneficial for the overall quality of the inspection work to strive for a greater level of objectivity, particularly when making comparisons over time. This could be achieved by making it easier for personnel to follow the set documentation routines, e.g. through more clear guiding instructions, standardisation in the documentation or more developed support or educating structures for the inspection and documentation processes.

The interviewed inspection personnel have described how specific forms and templates are used in order to standardise the inspection output. Specific acceptance criteria are also used in some power plants, but not all, which might facilitate the assessment process for the inspector. Conversely, at other power plants, the severity and size of all damage is assessed using a numbered system. Having both systems in place might facilitate a greater level of standardization and simplify the assessment process. Moreover, the system with two types of

¹⁴ Turesson, J., Vattenfall. Questionnaire, answered in September 2021.

¹⁵ Turesson, J., Vattenfall. Questionnaire, answered in September 2021.

inspections, where smaller inspections are documented in a less comprehensive manner, could benefit from being re-worked by introducing full-scale inspections as a standard. If an effective method of automatically storing digital photos was available, smaller inspections could possibly be replaced by simply documenting rooms and damage using photographs, skipping or reducing the report-writing stage. Harmonising the work methods and minimising the differences between the three nuclear power plants in question could be beneficial as it would not only create a greater comparativeness, but might also increase the overall routine quality. We suggest rotating inspection personnel between the power plants and thereby facilitating exchange in knowledge and experience.

3.1.3.3 *Advanced tools for long-term tracking of damage*

As has been stated previously, most damage, such as cracks, is repaired immediately. The few instances of damaged structures that are not repaired immediately need to be monitored until the next inspection. The intervals between follow up-inspections depend on the severity of the damage, ranging from a few months (or as short as necessary) to several years.

The damage is documented using photos and written documentation, but more detailed and specifically tailored methods for monitoring damage can be used as well. Results from these are not necessarily compatible with existing information systems, but if they are used in a very limited manner, this need not be an issue. As they can facilitate higher quality documentation, regularly implementing them can make for a higher safety level (as the human eye might not be able to properly identify differences in, for example, pictures over time) and lower maintenance and reparation costs. Sufficient quality improvements and cost reductions could motivate using more advanced tools to a limited extent separately from the main systems, e.g. SAP.

3.2 MAPPING POTENTIAL SOLUTION CONCEPTS

The current state analysis has led to the conclusion that a central objective is to simplify and reduce the time that is required for the documentation process, as it is disproportionately large. The conducted interviews and follow-up meetings with the concerned stakeholders have made it clear that the core issues are to be solved using solutions that premier simplicity, user friendliness and time savings. Therefore, it is implied that tools and methods that are recommended should be largely compatible and non-disruptive with and respect to current technical systems and inspection methods. The proposed solutions and recommendations will consequently be presented according to a categorisation of primary and secondary recommendations. The former would more strictly adhere to the aforementioned criteria, while the latter might deviate somewhat, but still be valuable if implemented in certain ways or circumstances.

3.2.1 Primary solutions

3.2.1.1 *Moving the documentation responsibility*

The simplest and most obvious way to ease the burden of writing up the report from inspections from the inspector is to appoint the task to someone else. Assigning a co-worker to a documentation or secretary role would clearly not change the total amount of time that is required for the documentation, but it would render it a non-issue for the inspection personnel.

This solution is favourable as it can be implemented relatively easily and in the short term. It is sustainable over time and compatible with all current systems and inspection methodologies - it virtually requires no adaptations from a systems perspective. There are no known major upfront investment costs, but given that more people are required, personnel costs would rise. This solution requires that the secretary has relevant skills (technical competence, knowledge of the construction in the facility and how to perform inspections). It also requires good communication between the inspector and the secretary. From an information safety perspective, this solution should not entail any drawbacks compared to the current practice. Naturally, this presupposes that the new/other employee would receive the appropriate safety clearance.

Furthermore, as the documentation process could be described as long and somewhat tedious, the inspector might become less willing or unable to document all relevant details in order to save time if they are responsible for it. Hence it is possible that the documentation quality would increase by having dedicated documentation resources.

3.2.1.2 *Speech dictation devices*

As has been stated previously, when doing an inspection round, the inspector uses ordinary pen and paper, and then re-writes the report on a computer. Aside from essentially doing the same work twice, which is ineffective and time-consuming, writing using a pen and paper is a relatively slow practice. By using a speech dictation device, inspectors could rationalise large parts of the documentation process. This could be achieved by using different types of tools, either modern smartphones/tablets, or dedicated dictaphones. Furthermore, regardless of which of the two is chosen, this solution could be implemented in (at least) two ways, with respect to the transcription process: Either a person manually transcribes the recording, or speech-to-voice software is used. Both phones/tablets and dictaphones are small and easy to carry, meaning that there should be few practical hindrances.

Using a phone or tablet for recording could initially be beneficial as most people are accustomed to using them in their everyday life, although dictaphones should be simple to use as well, despite their relative rarity. Phones or tablets offer potential synergy effects: The voice recording functionality could be used together with the camera functionality, and in the case of tablets also a document compiling app, in the same device. It is unlikely that phones or tablets have the option of connecting to the power plants' documentation systems directly but transmitting reports in word format should not be an issue.

Dictaphone manufacturers, as well as other actors, offer automated transcription software on the market and there are both offline and online variants available. In this context it is not likely that online solutions would be usable due to security reasons. This might be reconsidered in the future. There are speech-to-text alternatives that can be used directly in phones and tablets, and it is believed that this technology very recently reached a level of maturity making them very usable in both English and Swedish language. This is achieved by improved software and higher general performance of the hardware in phones and tablets, but also because these devices have been equipped with dedicated machine learning hardware that greatly improve its performance in this aspect. It has however not been established whether they yield transcriptions of the same quality as their computer counterparts.

A speech recording-oriented solution would be beneficial: The initial capital investments are relatively small and, assuming that the transcription software is a one-time cost, it is likely that there are essentially no running costs. Even if there would be certain software-related running costs, it is a relatively inexpensive solution. It would likely need a slight change to the work process, as it is believed that the text produced by speech recognition will still need to be subject to proofreading and at least some post processing.

3.2.1.3 *Bypassing the analogue step*

It has been made clear that documentation of the inspections is a central time-consumer. To reiterate, the documentation process is threefold: Preparations, documentation during the inspection, and post-inspection documentation. Currently the inspector needs to digitalise the inspection report between the second and third step, i.e. re-write what was written by hand on a computer and pair that information with the appropriate photos. Time can most likely be saved by removing the analogue step, meaning that the information would be written, or dictated, in a digital format straight away. This could be achieved by using some sort of mobile device, likely a tablet or laptop of sorts. It is noteworthy that ordinary laptops could be considered unwieldy in this context (referring to the intrinsic difficulty of carrying and using them while standing), which is why some sort of additional supporting tool would be required, or (more likely) by using a foldable laptop. A foldable laptop is one which can be folded in order to be used as both a tablet, with a touch screen, and a conventional laptop.

The advantages of using tablets or laptops during the inspections are, again, threefold:

1. The need to completely re-write the inspection notes in the post-inspection part of the process is removed, bringing about significant time-savings.
2. As most devices have built-in cameras, photo documentation could be inserted into the reports immediately, rather than having to waste time linking them together later.
3. The prospect of not having to write the reports by hand could compel the inspector to write a more detailed report, perhaps bringing about a higher report quality.

3.2.1.4 *Report structure and requirements*

Facility-specific report templates make up the foundation for the inspections in the sense that they guide the inspector's work and show which information is to be included. A more comprehensive and stricter template can increase the report quality and reduce the output differences between individual inspectors, however, there is no intrinsic worth in including more information for information's sake in a report: The included information needs to be relevant. Including unnecessary information can be harmful to the (perhaps perceived) usefulness and accessibility of a report as it simply drowns out and makes information of value more difficult to find.

With the above in mind, we suggest evaluating all included report elements with respect to whether they are needed and thereafter considering moving them from the inspection report to other documents. Although basic data and information pertaining to facility characteristics are valuable, they can perhaps be of greater use in dedicated base-documents, rather than inspection reports. As has been mentioned previously, this can slim the amount of data, making it easier to get an overview of the documentation. Moreover, it saves time during inspections, as less administrative work and information is required of the inspector. Another positive effect is that this can also make it easier to find the information that is moved from the inspection reports to dedicated, or otherwise more suitable, places.

Furthermore, we suggest investigating the possibility of introducing pre-filled out alternatives for the most common types of damages. The purpose of these standardised alternatives would be to minimise the amount of writing for each report. Practically this could, for instance, be a number of alternatives presented in check boxes. If no errors are found during an inspection, a simple "OK" would suffice, this should not have to be documented further. To be able to create a list of suitable alternatives an analysis of which types of parameters (type of damage, for example) are most frequently occurring in the reports, and it consequently also presupposes that certain types of parameters actually *are* frequently occurring. Although it is beyond the scope of this report to assess this type of reoccurrence rate, it is not unreasonable to assume that there is a certain amount of reoccurrences and hence a possible value in doing so.

Re-structuring report design and information structures in order to save time and bring about a greater accessibility to the information is a cost-efficient method which can be implemented using internal resources. To increase the likelihood of intercepting current best practices this work might be best done by a working group of inspectors from the different power plants. It would also seem likely that it could be implemented in a relatively short time frame. Furthermore, the fact that it is a simple rationalisation of existing structures and procedures means that no or limited change in the daily work, e.g. in the shape of education and new routines, would be required, which is not always the case when implementing new methods or technologies.

3.2.1.5 *Summary*

All in all, the aforementioned suggestions are likely low hanging fruit, that can be individually cherry-picked. However, revising the suggested tools, measures and

techniques, a more complete and rational “package” can be distinguished. This suggestion would comprise of the following;

- Use a large-display tablet for note taking, speech recognition and taking pictures.
- Develop revised inspection instructions and/or documents that contain all general information that does not change per inspection instance.
- Develop slim MS-Word-templates (.dot) for the documentation process, where mainly inspection-specific information is to be put in.

Using the above, multitasking with one open word document for documentation, the inspection instructions and the report from the previous inspection on a large display tablet, the inspection could be done using one single device. In case the picture quality from the tablets internal camera is not good enough, a separate camera could be used simultaneously, and the exact same pictures taken, saved for later to be replaced when post processing the Word document. Although speech recognition is probably very effective, using formal language when speaking can be somewhat challenging. Proof reading and a little post processing is likely unavoidable, but if this could be done directly in a nearly finished digital document, this will potentially be a briefer task.

3.2.2 Secondary solutions

As has been mentioned previously, the distinction between primary and secondary solutions in this report is intended to illustrate how the primary solutions are simpler and less disruptive to the systems and methods in use. The secondary solutions, on the other hand, are solutions that are deemed as likely to improve the inspections, but might, for example, require larger investments or changes, or they might act as independent solutions for specific applications and situations. They are generally more technologically advanced and offer different kinds of value compared to the primary solutions.

A possible future solution is to separate photo documentation from documentation of damages, with the aim of automating the collection of photo documentation. Making the latter more or less automatic, and pair this with a system of storing pictures in an accessible and also automatic way, could allow for a much more extensive use of photos. In summary this could mean automatic storage and browsing of pictures, only using simple metadata as; time, position and direction of camera when photo taken. In this way, a *small inspection*, as mentioned under *chapter 3.1*, could be documented using only a checkbox “no remarks” and a bulk of automatically processed photos.

Complementary to the above, damages, including both visible damage and potential damage/risk, can be documented separately, either similarly as today using a simple Word document, or using a database approach, where every damage are given a serial number, a location, time first discovered, comments, assessments, risk evaluation etc., and specifically location.

Using a damages’ location in space and time, relevant photos can be filtered out for

use when reviewing and assessing a damage, including pictures before the damage was first discovered.

It is our belief that a similar system would free up time and resources for the inspector to mainly focus on finding and assessing damages and risk, while upholding a much more comprehensive documentation.

Using this approach, a key instrument is capturing pictures and metadata in an effective way. This is an area highly affected by recent technological advancement in drone, digital cameras, positioning systems and robotics.

3.2.2.1 *Drones*

Drones can be useful, especially outdoors, inspecting structures that are hard to reach. At least four types of improvements can be achieved by using drone technology:

- 1) The existing nuclear power plants in Sweden are relatively tall buildings. Drones could be used to survey and photograph inaccessible places, both on the inside and outside of the facilities. The need for rope climbers and similar activities would thereby be reduced and in doing so the inspection time would be reduced. This could bring about cost savings from the reduced need for scaffolding and cranes as well.
- 2) It is likely that the photo quality would improve when using drones to photograph inaccessible places; drones are likely able to photograph from more favourable angles and are more stable, compared to a human. It is also possible that it would be easier to compare photos between inspections, as the drones could more easily be positioned in the same spot as during the previous inspection.
- 3) Drones are also advantageous as it increases the safety for the inspection personnel. Using them where people would otherwise climb reduces the risk of falling, and they can also be used in contaminated (radioactive) areas.
- 4) Drones for inspection use are always equipped with GPS, and some can use RTK-GPS (Real Time Kinematics) for very precise positioning. This can be used to automate photo documentation series, making them very efficient to perform and completely repeatable.

Generally speaking, drones are also favourable as they allow the inspection personnel to focus on assessment and documentation, rather than the process of climbing. Drone technology should be seen as a complement to the tools listed under heading 3.2.1 - Primary solutions. Drone technology can be somewhat expensive, both as an initial investment and "crash insurance", but also as there needs to be a skilled pilot to fly the drone. This however can be mitigated by pre-programmed repeated photo-jobs.

3.2.2.2 *Digital camera and repeat photography*

Capturing photos using a digital camera would be considered the most obvious for in-doors applications. Outside, some cameras and all phones have built-in GPS and

compass to also capture required metadata, but inside this method needs to be complemented.

Repeat photography is the practice of taking multiple photos of the same subject, from the same location, at different times. It is a technique for observing changes that occur during an extended time period, making it inherently interesting to use at inspections. Using repeat photography could simplify inspection processes and comparisons over time as well as increase inspection quality. This means that if points of damage are not to be repaired immediately, they can be more accurately tracked, as comparisons are easier. Also, if a picture was taken at the right spot before a damage is first observed, important information on events leading up to the damage might be found.

To be able to compare images of a subject in an effective way it is preferred to have photos taken as similar as possible regarding distance and angle etc. It can be a bit challenging to achieve this manually but there are helpful tools to use such as overlay technique. By using a reference picture as an overlay, slightly transparent in the screen, the photographer can adjust the camera and take a new image fairly similar and thus comparable to the old one.

Similarly, if this technique is built into an app directly communicating with the picture database and maintenance system, the app could simply request the operator to take one or a series of photos, based on, for example, what room the operator is in. If the app uses an overlay image, taken at a known location, to guide the operator, the system will have a pretty good idea where the new picture is taken too. To verify this both machine based and manual verification are viable options.

Repeat photography with overlay technique is available as a mobile phone application, but very rudimentary and mostly in the form of “toy”-style apps. To use this method effectively, it is believed that a more purpose-built app must be developed, making this a relatively extensive project that likely lies outside what is possible to do within the scope of just documenting inspections of concrete structures within nuclear power plants. However, as this would obviously be a versatile tool, useful in many other industries and use-cases, finding a platform to cooperate in developing this as a more general tool, might still be an interesting option.

3.2.2.3 *Photogrammetry*

When a large enough data-set of positioned images has been collected, it would probably be possible to automate positioning indoors by applying a photogrammetry-like technique, where a trained machine-learning algorithm can recognize and position new images as they are collected. This would probably need specifically developed software, and since another way of positioning the initial, quite large, dataset, it would seem to be a secondary option.

3.2.2.4 *Capturing images using robotics*

Another method to do repeat Photography positioning images taken indoors with great precision is to use a total station and a local network of reference points.

Doing this manually, or semi-manually with a robotic total station, will probably be a very time-consuming process, but other options has recently been developed. Using a semi-autonomous robot such as Spot¹⁶ see Figure 1, that already has developed software for automated visual inspections, can use as a suitable practice vehicle and reference point when looking for a tool suitable specifically for inspecting and documenting concrete structures in nuclear power plants.

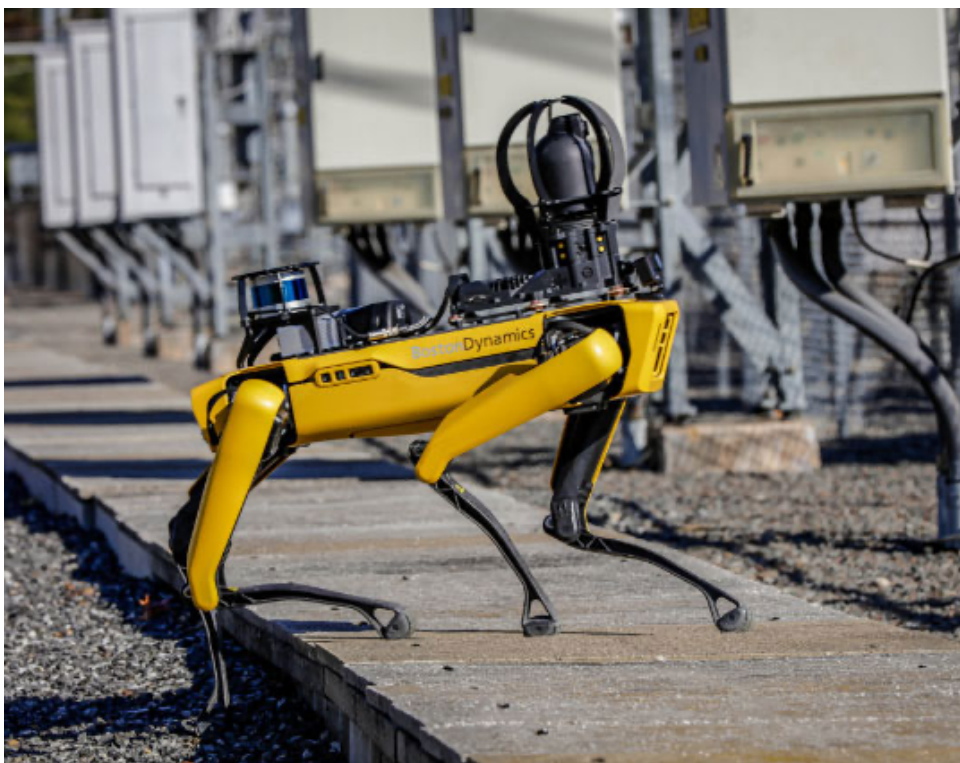


Figure 1. Spot, semi-autonomous robot specifically equipped for autonomous visual inspections. Press-picture from Boston Dynamics.

3.2.3 Discarded or suboptimal alternatives

During the process of identifying and compiling possible solutions for improving the inspection procedures, several potential solutions have been discarded due to them being nonviable, not adapted or developed enough or otherwise suboptimal. The following listed solutions are of the aforementioned kind and are included in this sub-topic to provide more comprehensive results and increase the knowledge level of nonviable solutions as well.

3.2.3.1 BaTMan

During the initial phase of the project, a number of interviews with non-nuclear power plant personnel were conducted, and several mentioned that The Swedish Transport Administration, Trafikverket, had developed their own system for somewhat similar purposes. In order to gain greater insight into how Trafikverket administer their inspections of bridges, tunnels and other infrastructure, an

¹⁶ Spot, Boston Dynamics semi autonomous robot, applications for visual inspections already available.

interview was set up.¹⁷ In the interview it was described how a system called BaTMan was developed by Trafikverket's predecessors, the administrations for roads and railways, Vägverket and Banverket, respectively. The system was developed during the early 2000's and is used by a number of large owners of civil infrastructure, thereamong being Stockholms regional traffic administration (SL), Swedavia, the Port of Gothenburg, as well as 106 Swedish municipalities. Although the system is becoming slightly outdated, it is well tested.

BaTMan was of interest as it allows data and information to be entered directly into the system, without using any templates, documents or similar, and produces structured meta data which is searchable, e.g. it lets the users search for specific damage classifications. The system allows photos to be coupled to certain points of damage and compare those with photos from previous inspections. The system prompts inspections every sixth year as a rule, but this can be adjusted.

Trafikverket does not store confidential information in BaTMan. It was stated in the interview that some data is exempt from being entered into the system, but that it is a system for documenting damage to concrete structures, not system functionality, and therefore the security risk is acceptable. It is concluded that the system is not built with the purpose of being private and secure, as many actors need access to the information. The interviewees pointed out that there are four criteria which need to be balanced: Availability, confidentiality, accuracy and traceability. The BaTMan system cannot handle other types of files, such as 3D-models or similar; information must be entered directly into the program.

A significant amount of work is required to migrate from one documentation system to another and is something that the project group has explicitly stated will not happen in the short to medium term. Moreover, although the system is well suited for documentation and tracking of a large number of structures and points of damage, it might not be optimal for nuclear power plants because of the system's inherent openness. I.e., the nuclear power industry's more rigorous security and confidentiality levels disqualify more transparent documentation systems, which, in its current state, consequently also disqualifies BaTMan from use in the Swedish nuclear power plants. Even though the system is becoming slightly outdated, it is noteworthy that on a conceptual level BaTMan is partly similar to what might be sought after.

3.2.3.2 *Building Information Models*

Building Information Models, or BIM, were initially considered as a possible solution. BIM software offers the possibility to create virtual models of buildings, where information, such as inspection reports, can be attached to specific locations. The information can be shared between personnel with access to the software, which would be required if applied to the nuclear power plants. Although the fundamental functionality of BIMs is aligned with the needs described in this report, there are several caveats to be considered.

It has been concluded in the market analysis that BIMs are primarily employed in the construction sector, and interviews have indicated that there is a clear

¹⁷ Håggström, J. and Olsson, F., Trafikverket. Interview, October 7, 2021.

advantage to using BIMs when there is extensive knowledge of the construction. By implication this means that it is difficult to create a BIM-model for an existing structure due to the complexity and required amount of up-to-date information, and even more so when the structure is of a larger size. Although it is possible to create simpler BIM models, for example by removing some *smart* features and functionality, this would mean that a large amount of work would result in a limited worth and hence a questionable effectiveness of the investment. There are a number of BIM-solutions that are commercially available, for example Trimble and Solibri, and Skanska, a large Swedish construction and contracting company, uses it extensively in construction projects. This implies a certain market and product maturity.

In order to grant access to the users, in this case the inspection personnel, most BIMs employ a cloud solution. Cloud-based solutions have been explicitly disavowed by the project group in order to ensure a high level of information safety, both with respect to potential security threats, but also to ensure access to information. Moreover, there is a risk that there would be at least some degree of lock-in effects, risks with proprietary software and consequently possibility of data and information losses in the event of a discontinued product support. As with the reasoning with the BaTMan system, migrating all information to a BIM-based system would entail a very large amount of work as well, which is not desirable. A system migration would likely not be seamless, and some information might either be lost or unable to be entered into the new system. In the case of a post-BIM-implementation system migration from one BIM solution to another, the underlying data and information (e.g. inspection reports) would likely be preserved, but in-program information, for example connections between documents and locations, might be lost. This highlights the need for sustainable long-term solutions.

There are some continuous financial impacts of implementing an external BIM-system, as license costs would incur, but also personnel costs for maintaining and administering the system, as well as costs for educating the inspection personnel in how to use the system. The system's sheer size and complexity can be considered a significant risk, both when setting up the system, but also for the inspectors that are to use it. To summarize, using a commercial BIM system could prove advantageous, but there are considerable risks with respect to information safety, migration issues, long-term sustainability and workload associated with setting up and maintaining the system, as well as the questionable ease of use for the personnel.

3.2.3.3 *Creating models using laser technology*

Similarly to how 3D-models can be created using drones, they can also be created by using stationary laser equipment. Laser scanning is relatively simple to use in the scanning phase, as modern equipment is highly automated. However, the process of creating point clouds and processing the output from the equipment requires a certain skill set, and the equipment is relatively expensive. The point based cloud (3D-model) should be consistently maintained and worked with, wherefore resources would be required for that as well. Moreover, in the meetings with the project group, it has been stated that for a tool to actually be considered

usable, it needs to be relatively simple, why this might not be an optimal solution, but perhaps an alternative in certain areas where greater detail is required.

This type of equipment should not be dependent on regular software updates, making it durable and independent over time, decreasing the risk for lock-in effects. It is not clear, however, if the output data and related software is of a proprietary nature. As was described in the case of the drone technology, laser technology can be used as a niche solution for when following up on specific points of damage, as well as in areas of high importance. As there is a great number of rooms in each facility (in the hundreds, as an order of magnitude), it would be considered not only too great a task to scan all of them, but it is questionable whether all of this information would be useful, considering the majority of all damage is repaired almost immediately. There is nonetheless great value in having extensive information available over time when it comes to critical functionality. In this case, however, it comes at a cost of greater complexity and required skill sets and resources.

3.3 COMMERCIALLY AVAILABLE SOLUTIONS

Some of the potential solutions that have been discussed in 3.2 Mapping potential solution concepts are improvements which do not require investments, whereas others are commercially available products or services. In an effort to reflect what is publically available on the market, an overview of some solutions will be presented in this chapter. The purpose is not to create a conclusive list of alternatives, but rather to provide examples of possible solutions.

3.3.1 Speech dictation devices

Speech dictation will be considered as an alternative using both mobile phones or tablets as well as dedicated dictaphones. Both enable the user to save information either as audio files or as text, if speech-to-text software is used.

Using a smartphone or tablet

Modern smartphones as a rule have built in dictation functionality, and it was, for example, implemented as an offline function in the iPhone 6s (2015). Both iOS and Android units have built in dictaphones (speech to text software) in the keyboard with no need for third party software. To use it, one opens the desired document and presses the microphone button to start dictating. The performance and accuracy of speech recognition has increased substantially and matured - they are currently at a level where the devices will capture speech at very rapid talking speeds, both offline and online.

Captured speech would probably most efficiently be done directly in the word processing software used for documentation, MS-Word or similar. Sound files captured can, if needed, be transferred to a computer for further processing or archiving.

Using a dictaphone

The market for dictaphones is relatively mature and has a number of established actors which offer their products, for example Sony and Olympus, but the market is shrinking as the same functionality is generally available in abundant cheap phones. Dictaphones are in general easy to use, small and easy to carry. This is illustrated by Sony's voice recorder model TX800 (see [link](#)), which weighs 22 grams and has the dimensions 3,8 x 3,8 x 1,37 cm. Olympus offers similar products, e.g. the DS-9500 (can be found [here](#)). Sony does, however, not offer any speech-to-text software, and neither does Olympus, but Olympus offers a transcription product consisting of transcription software and a foot pedal, used when transcribing text ([link](#)).

The fact that they do not offer automatic speech-to-text software is not an issue if there is dedicated transcription personnel, but if not, a third party software provider would be required: IBM [offers](#) speech-to-text software. It can be used offline and handles bundles of audio files (documentation can be found [here](#)), and although it does not support Swedish, it could potentially be used in the future. To ensure high quality transcriptions in Swedish today, a manual transcription solution would likely be needed. An application called Snotes enables downloading of language packages and can thereby be used offline.

An example that has been found is the healthcare administration in Skåne (Swedish: *Region Skåne*). Correspondence shows that they use a voice to text software by Nuance for documentation in their journal systems. The software is not integrated into the journal system, but allows the user to, by choosing the desired field or document, to enter text by speaking. The software has a specific medical dictionary, which likely could be adapted to the inspection context. However, the healthcare administration highlights that they differentiate between voice-to-text software and transcription; they use the latter as well but in that case, a recorded audio file is sent to and manually transcribed by a secretary. According to the conducted market analysis, this essentially illustrates what is offered by the market: Either a live, speech-to-text functionality or using manual transcription.

3.3.2 Tablets and laptops

As was described in 3.2.1.3 Bypassing the analogue step, process simplification and time reductions can be achieved by not having to write and re-write information by hand. Bringing laptops or tablets on the inspection rounds is a simple measure to avoid this type of double work.

Tablets are widely available and simple to both use and carry. The ease of use is a considerable advantage and common document software, MS Office, is readily available for iOS and Android.

Conventional laptops could, as has been mentioned previously, be considered unwieldy to carry and use while standing, and therefore we suggest exploring the use of foldable laptops. These allow the user to fold back the keyboard behind the screen and the laptop assumes the shape of a tablet. This is advantageous as it means that the inspection personnel can use the same device while doing their inspection rounds as well as when working at their desk. Note that laptops with

built in fans can be contaminated when used in certain rooms. If a laptop is to be used in that kind of area, it needs to stay on the contaminated side. Moreover, it is also possible that the power plants' documentation systems are only accessible via computers, and not by using tablets. The use of foldable laptops as such should not entail any considerable lock-in effects nor effect any long-term costs, as computers must be replaced sooner or later regardless. Lenovo can be considered a pioneer in the area of foldable laptops, and has released several models, e.g. [ThinkBook 14s Yoga](#) and [ThinkPad X1 Fold](#), which would be suitable. Due to the multi-area-use of laptops and the aforementioned advantages compared to tablets, they are likely a more sustainable alternative.

3.3.3 Drones

The commercial market for drones has become more mature during the 2010's. In order to operate drones professionally, educating personnel or hiring contractors is required. Drones can either be bought for inhouse usage or rented, potentially as part of a larger service package. There is a multitude of drone manufacturers and brands, for example DJI, whose model [Mavic 3](#) produces high quality photos. There are also more, but not prohibitively, expensive options that include RTK level positioning. The drone quality varies primarily within the offered price ranges, rather than between the manufacturers.

The project group has indicated that control and security is to be prioritised, wherefore hiring contractors or consultants externally is disadvised, and consequently purchasing drones and educating internal personnel is the only viable alternative. The solution with drones can be useful in certain context, where it may prove to be more cost efficient than the alternative approaches.

3.3.4 Photo comparison / repeat photography

A helpful tool when taking pictures of a certain subject, from the same location, at different times, is the overlay technique. There are a few apps available for iOS like *Recreate* and *Photos Then and Now* for example. Any photo on the phone can be used as a guide for taking new ones, to match the pose, composition and layout in a similar way. Note that this technique is helpful but not precise. These apps can be described as a little gimmicky or "toy"-apps.

3.3.5 Software suites for documenting constructions sites and progress

Several software packages are available mainly aiming to aid in documenting construction sites. The construction site is documented by large series of still pictures, drone pictures and 360 camera walk-throughs. Generally, these services are subscription- and cloud based. The contractor uploads photo documentation (and plans in some cases) continuously during the construction phase, and the tool can be used to "rewind" the process if necessary to examine for example how a foundation was prepared, where electrical conduits were placed before plasterboard is fitted etc. One can obviously see the parallel to an application where an owner of a large civil structure would like to regularly document "everything", to be able to ocularly follow slow degradation and subtle changes. It is very much the same application but on a different time scale, ranging from years

to decades rather than days to months. DroneDeploy is one vendor that was contacted and while very keen to market their product, and underlines that it is used at more than 100 nuclear power plants world-wide, it is strictly offered as a cloud service, and the lock-in effect is very obvious.

If a similar tool could be found or developed elsewhere, that enables the owner to control all data and manage the information themselves, it could prove to be a very effective tool for documenting inspections of concrete structures.

4 Discussion

4.1 SUGGESTED SOLUTIONS

The aim of this research has been to map possible solutions for rationalising inspections of the Swedish nuclear power plants, primarily via digitalisation. The project group's directives have made it clear that stability and security are prioritised factors in this context, and that no major systems changes will be implemented in the short to medium term. This, i.e., mandates solutions that:

- are sustainable in the long term
- are largely compatible with current systems and processes
- do not create lock-in effects

Larger systems or procedural changes require thorough preparations and planning, and systems migration can have unforeseen consequences, such as limited backwards compatibility or loss of information. Therefore, replacing the main (documentation) systems has been placed outside the scope of this study, and the project requirements delimit the possible scope of improvements to incremental process changes and smaller additions. On the other hand, some solutions which act as process-wise satellites, complements to existing processes, have been included. The identified solutions that have been discussed in chapters 3.2.1 are primarily of the former kind and those found in 3.2.2 of the latter.

The identified *primary solutions* (see chapter 3.2.1 - Primary solutions) are generally of a relatively simple kind, but nonetheless have a large impact potential. Implementing specific combinations of them could result in certain synergy effects: Improving the report structures and templates would likely be beneficial regardless of other improvements, meaning it can be combined with any of the other suggestions. Conversely, there would be a limited benefit to having both a dictaphone and laptop/tablet on the inspection round. If additional documentation personnel can be hired to join the inspection round and they can bring their laptops, it would likely be more efficient than if the inspector would need to do it on their own. All of these solutions:

- Can be implemented in the short term
- Do not create lock-in effects
- Require no major systems changes
- Have low-to-medium cost levels
- Reduce the required documentation time for the inspections
- Reduce the workload for the inspection personnel

and are therefore recommended.

The secondary solutions, presented in Chapter 3.2.2, should be viewed as having satellite-like properties in the sense that they have limited potential for being integrated into the current systems, such as SAP and the documentation systems. They can nonetheless be of use in certain situations, such as in difficult-to-reach places, areas with critical functionality and when certain points of damage need to

be monitored over time. Certain caveats apply to both drone technology and robotics, such as:

- Require a certain skill set or education
- Difficult for the inspection personnel to use or bring with them on inspections
- Being expensive
- Non-integrable with current systems

Repeat photography and photogrammetry is a functionality which is shared between several of the mentioned technologies, such as drones, ordinary digital cameras and robotics. They can be of value but it is questionable whether it would be of much use in a context where there is not much need for continuous tracking of specific points of damage (as they are generally not left to deteriorate over time, but are repaired instead).

4.2 LONG TERM STRATEGY

Leaving the topic of the applicability of the recommended solutions, there is an overarching discussion to be held regarding the *strategy* under which the inspection methodology, documentation systems and other types of information technology support fall under. It is clear that there is a need for improvements in certain areas, as has been outlined in this report and in the conducted interviews. The systemic weaknesses have also been, at least partly, identified in this report and by the project group itself. It can therefore be agreed upon that there is a consensus regarding what is suboptimal in the current system. There is also a general consensus on demands and requirements for prospective system solutions, which implies that there is agreement on which qualities and functionalities an ideal system should have.

A next step could be to develop a long-term information strategy. The strategy could encapsulate and clarify what demands to put on IT-systems in the short, medium and long term, conceptualise the design of an ideal documentation system in the long term, establish clear goals and how to realise them. A further analysis of the potential benefits of a system which is adapted to a larger extent than the current ones would likely be required. In interviews and dialogue with the project group, an ideal system has been described as one which acts similarly to a Building Information Model, where inspection reports can be attached digitally to specific locations and be used to compare reports over time. It should also be secure, locally hosted, sustainable over time, non-proprietary, etc. This relates to the fact that two large organisations, Électricité de France (EDF) and the Electric Power Research Institute (EPRI) in the US, have been asked whether there are any similar systems in place in their respective organisations. The former has confirmed that there are no such systems, and the latter has been unable to confirm the existence of any similar systems.

By extension, the above indicates that there are no fitting solutions available on the market (and none have been found as part of the conducted work in this report), and that if there are any locally developed solutions in other nuclear power organisations, they are not widely available. This, in turn, implies that there might be a need for in-house development of a suitable system, given that the

aforementioned strategy does not conclude that the current IT-infrastructure is satisfactory in the long term. This is similar to what the Swedish Transport Administration (Trafikverket) has done with BaTMan, more than 20 years ago. This would, yet again, presuppose a clear long term strategy, but it would also be beneficial to conduct this work jointly between the owners of Forsmark, Ringhals and Oskarshamn nuclear power plants, as the needs and pre-requisites are largely similar. There is also a possibility that organisations internationally would be interested in such a system.

5 Conclusion and recommendation

To conclude, a number of possible measures, solutions and tools, all with different characteristics, have been identified. The solutions have been divided into two categories, primary and secondary solutions, via the structure of this report, where the former may act as high-impact process development within existing systems, and the latter primarily be used in certain circumstances, separate from the primary inspection methodology. The identified measures have different estimated impact on the time savings for the inspections, financial consequences, ease of use, skill and education requirements, possible integration levels with the existing systems, functionalities, and so on. This means that all alternatives and consequences must be considered before choosing and implementing a measure, and that there is a need for a holistic approach to the evaluations. As the purpose and areas of use vary as well, implementing a mix of the tools and measures is recommended.

We highly recommend optimizing the report template, in word format, and use a tablet during the inspection. By downloading the template to a tablet, the inspector can use built-in functions to create the inspection report without having to bring any extra equipment. Use the tablet's camera to insert images directly into the report and add text through the keyboard or by using the built-in dictation speech-to-text function. The inspector can thereby create a document that potentially will require only proofreading and very little post processing.

Moreover, we recommend investigating how useful the solutions described in 3.2.2 Secondary solutions would be to the inspections and implementing them according to the results. It is noteworthy that the presented solutions do not represent changes which will lead to an optimal documentation process and structure; A more fundamental overhaul, including a long-term strategy and likely developing a new, tailored documentation system, would be required to achieve more pervasive results, as was discussed in chapter 4.2 Long term strategy.

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MAKING INSPECTIONS OF CONCRETE STRUCTURES IN NUCLEAR POWERPLANTS MORE EFFICIENT

This report aims to identify and evaluate commercially available digital tools which can be used to simplify and streamline the inspection process. The report describes how inspections are carried out today and in which manner the inspection process could be improved. Identified tools for this purpose are listed and evaluated. They have been classified as primary and secondary solutions, where the former may act as high-impact process development within existing systems, and the latter to be used in certain circumstances or in a future when upgrading current systems.

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