Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Information Technology and Electrical Engineering
Department of Computer Science

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NOLAS Insights

Systemizing operational characteristics in an organization consisting of several functional units

Master's thesis in Computer Science
Supervisor: Rune Sætre
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Kunnskap for en bedre verden

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Abstract

Norwegian Air Ambulance (NAA) is a private company that delivers air emergency services to the government of Norway and Denmark. NAA has 12 bases in Norway and 4 in Denmark. Data about the emergency operations are tracked to see developments in the service and to verify that the requirements of NAA's service contract are fulfilled. This thesis presents a business intelligence system, named NOLAS Insights, that simplifies analysis of operational data. The system extracts data from NAA's database system and visualizes operational characteristics. The development and evaluation of five prototypes was done with a user-centered approach based on the research strategy: Design and Creation. The prototypes were evaluated by participants from the NAA management through user testing and interviews. The user tests discovered usability problems that were solved, and the interviews helped to prioritize functionality and determine the user satisfaction with the system. The interviews showed that NOLAS Insights can be useful for the management team and has a great potential in the future. The system offers NAA a tool that provides information that can assist in decision-making and automates the creation of different types of performance reports.

Sammendrag

Norsk Luftambulanse (NLA) er et privat eid selskap som tilbyr luftambulanse-tjenester i både Norge og Danmark. NLA har 12 baser i Norge og 4 i Danmark. Virksomhetsdata vedrørende tjenesten registreres fortløpende for å se tjenestens utvikling og for å verifisere at kontraktkravene opprettholdes. Denne oppgaven presenterer et virksomhetsrapporteringssystem, NOLAS Insights, som forenkler analyse av operasjonelle data. Systemet henter data fra NLAs databasesystem og visualiserer operasjonelle karakteristika. Utviklingen og evalueringen av fem prototyper ble utført med en brukersentrert tilnærming basert på forskningsstrategien: "Design and Creation". Prototypene ble evaluert av deltagere fra NLAs ledelse gjennom brukertester og semistrukturerte intervjuer. Brukertestene identifiserte brukbarhetsproblemer som ble løst. Intervjuene bidro til prioritering av funksjonalitet og til å kartlegge brukertilfredshet med systemet. Intervjuene viste at NOLAS Insights kan være nyttig for ledelsen i NLA og har et stort framtidig potensiale. Systemet gir NAA et verktøy som tilbyr informasjon som kan underbygge beslutninger og bidrar med å automatisere prosessen for å hente ut rapporter om tjenestens utvikling.

Preface

This thesis was made as a completion of two Master of Science degrees in Computer Science at the Norwegian University of Science and Technology (NTNU). The work started in the fall of 2018 and was completed in the spring of 2019. Taking part in the digitalization of the Norwegian medical emergency service is motivating, and it was therefore satisfying to get positive results from the project.

We would like to thank our supervisor Rune Sætre for useful guidance and our co-supervisors Andreas Krüger and Lars Eide Næss-Pleym for their continued support and engagement in the project. The assistance offered by Yngve Dahl was also greatly appreciated. From Norwegian Air Ambulance (NAA) we would like to thank Rune Midtgaard, Bo Conneryd, André Thoresen and all management team members who participated in the user test sessions. Their willingness to participate and to be an active part of this project was crucial.

To make sure that we were able to make the delivery on time, we used Toggl[1] to track time spent working and Trello[2] to organize the work into smaller tasks. These tools show that we spent a total of 1274 hours to complete 308 tasks in the spring semester of 116 days.

We also want to acknowledge our family and friends to show gratitude for their continued support and help. A big thanks to Even's family for letting us stay with them during our visits to Oslo.

Marius Setalid & *Even Skari*

Trondheim, June 11, 2019

[1] https://toggl.com/
[2] https://trello.com/

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Abbreviations

API	=	Application Programming Interface
EMS	=	Emergency Medical Services
GUI	=	Graphical User Interface
HCI	=	Human-Computer Interaction
ICAO	=	International Civil Aviation Organization
JS	=	JavaScript
JSON	=	JavaScript Object Notation
NAA	=	Norwegian Air Ambulance - Norsk Luftambulanse (NLA)
NAAF	=	Norwegian Air Ambulance Foundation
NTNU	=	Norwegian University of Science and Technology
REST	=	Representational State Transfer
SPC	=	Statistical Process Control
SPI	=	Safety performance indicator
UCD	=	User-centered design
UI	=	User Interface
UX	=	User experience

Chapter 1

Introduction

The aim of this project revolves around the creation of NOLAS Insights, a system capable of visualizing certain aspects of the air ambulance operations of Norwegian Air Ambulance[1] (NAA). This chapter presents the motivation and background for the thesis, the research question, and contributions of the project. The chapter continues with an overview of the research method, desired system properties, and related work. At the end of the chapter, the structure of the thesis is outlined.

1.1 Motivation and background

In a world full of people, medical emergencies are bound to occur, whether it is a heart attack, a car crash, or a major incident involving casualties. Fortunately, emergency medical services (EMS) exist to deal with situations like this. In preparation for these inevitable occurrences, it is critical that the medical emergency services are equipped with the best possible information to deal with these events. NAA is an operator of helicopter-based air ambulance operations with 12 bases in Norway and 4 bases in Denmark. NAA's activity consists of complex air operations. The purpose is to offer specialized emergency medical care to severely ill and injured patients. NAA's goals are as follows:

1. Deliver a service that is always available;
2. Give the patient the best possible treatment;
3. Comply with safety regulations from the aviation authorities.

The thesis was motivated by finding a way to assist the services of NAA, and through discussion and brainstorming with the supervisors, NOLAS Insights was established. Initially, the plan was to do real-time transmissions of data between airborne ambulances,

[1] https://norskluftambulanse.no/

regular ambulances, and the emergency center. This involved capturing various instrument values describing patient health throughout the trip and generating a report to assist in taking the next necessary medical steps at the hospital. However, this would require multiple approvals and was problematic in terms of the project's short time frame. An air emergency doctor came up with the idea of creating NOLAS Insights and proposed the idea to the CEO of NAA.

The CEO saw potential in the idea and wanted to explore the full extent of it. NAA uses performance targets to determine how helicopter bases are performing, but this process is done manually. The data is retrieved from NAA's database system called NOLAS. NAA's tedious manual process of getting an overview of the different performance targets demands a tool that does this automatically. A tool that gives an overview of the organization and individual bases, with easily accessible information to assist in decision-making. By communicating back and forth with NAA, the initial scope of the project was shaped.

1.2 Research question

There are many factors to consider when creating an overview of NAA's operational situation. As the management of NAA is a specific group of users, it is critical to test the product on them. To tailor a product to a specific user group, it is important to understand the context of use, and to do evaluations with users that are going to use the system. The user-centered design approach revolves around heavy user involvement during the development, with the goal of making the application intuitive for the intended user group. In addition to the goal of creating something intuitive, it must also be useful. To provide useful information, data fed from the NOLAS database can be analyzed and visualized. The usefulness revolves around seeing how the operational processes develop over time, being able to compare developments, and finding trends. Ideally NOLAS Insights will be a tool that systemizes existing data into useful knowledge not previously available to the NAA management team. To summarize, the thesis' focus was to understand the role of the user in the system and to improve data visualization, and to answer the following research question:

Research question: Which design considerations must be made to give the user an overview of the operational situation?

1.3 Contributions

This project's main contribution is the product called NOLAS Insights. The application gives an overview of the operations of NAA. This requires a robust system that automates the process of gathering data from relevant sources, and that visualizes useful data in an intuitive way. The useful data consists of operational characteristics that gives the management of NAA an overview of historical developments and trends. The system offers

NAA a tool that provides information that can assist in decision-making and automates the creation of different types of performance reports.

Through evaluation of the system, knowledge will be gained regarding the importance of design considerations when designing a system with focus on usability. The iterative development approach ensures that multiple design choices can be tested and evaluated.

1.4 Research method

Oates' model of research (Oates, 2006) was used to define the research method in the present project, and is discussed more in depth in chapter 3. The research method defines a work process which is chosen in order to answer the research question. As the research involved measuring the impact of different design choices, it is natural to apply iterative prototyping to get feedback. The Design and Creation strategy was used to guide each iteration, and the approach is inspired by user-centered design.

The prototypes were evaluated through five user test sessions. The user test sessions consisted of the user executing a set of tasks followed by an interview about the experience. The qualitative data gathered from these tests will be used to answer the research question.

The development approach of the system was explorative, and the results from the user test sessions will guide the prioritization of functionality. NAA is currently improving and expanding the tracked operational data, and NOLAS Insights will function as a tool that shows what is possible given the right data. A more well-defined approach with strict system requirements would likely result in a more predictable system, but NAA would rather have the benefit of new features being added at later stages of the project.

1.5 Desired system properties

While the explorative approach does not involve strict system requirements, the system needs a set of properties to be based upon. The desired system properties took shape gradually in the preliminary study through exploration of the problem, discussions with stakeholders, and evaluation of the first prototype. They are summarized in table 1.1.

The most critical properties are related to NOLAS Insights relying on the database system NOLAS. In order to visualize live characteristics of NAA's operation, data must be extracted from NOLAS. Fast data extraction is preferred, as it will decrease the loading time. The data contains highly sensitive information, and it is therefore critical that the data is kept secure.

In order to continue their operation, NAA must deliver a level of service that meets certain requirements, and uncovering operational trends related to these requirements would therefore be of value. Most of the requirements relate to contingency measures and safety violations. Prediction of future trends would make precautionary measures possible and

#	Property	Priority
1	Extract operational data from NOLAS	Very high
2	Secure extracted data from NOLAS	Very high
3	Determine operational trends	High
4	Visualize operational characteristics for bases	High
5	Compare operational characteristics in a period to prior periods	High
6	Compare operational characteristics in one base to another	Medium
7	Export of graphs and data	Medium
8	Customizable experience for each user	Low

Table 1.1: The desired system properties of NOLAS Insights established in the preliminary study.

could prevent requirement breaches; however, determining future trends with accuracy is not straightforward and finding historical trends might be a more viable alternative.

The next properties are related to the visualization of operational characteristics describing the performance of NAA's different bases in different categories. Examples of operational characteristics are the availability of a base's service and the number of missions executed in a base during a period. Table A.1 shows a summary of the 19 operational characteristics that NAA desired at the start of the project.

The managers of NAA each have different responsibilities and have different uses of the application. It was therefore desirable to have a customized view based on the user's focus area. Many users also wanted export functionality to be a part of the system, both in regard to exporting table data to Excel and exporting graphs easily to presentations.

1.6 Related work

The considerations when it comes to the design of information systems is something all developers have to keep in mind and is an important area of research. (Franz and Robey, 1984) argue for a dual perspective where system development consists of a rational and political process. The rational part revolves around the rational objectives and methods in development, whereas the political process involves the actors' self-interests for controlling the development while avoiding blame. (Nielsen, 1995) defines 10 usability heuristics that work as guidelines for interaction design. These include always showing the user what is going on, speaking the users' language, and providing the user with consistency when accomplishing tasks. An important factor for new information systems is the level of user acceptance, and (Davis, 1993) created a technology acceptance model that specifies relationships between properties like design features, perceived usefulness, and actual use. In the study, they found that perceived usefulness had 50 % more impact than the ease of use for system adaption. The work of (Olson and Ives, 1981) focused on demonstrating the link between the success of a system and user involvement and found a correlation between system success and increased level of user involvement.

1.7 Thesis structure

This section presents an overview of the thesis structure and the purpose of each chapter.

Chapter 1: Introduction presents the motivation for the project, research question, contributions, research method, desired system properties and structure of the thesis.

Chapter 2: Theory explains design theory essential to the project.

Chapter 3: Research method details the research method used in this project. It presents the research strategy, Design and Creation, and the data generation methods that were used to answer the research question.

Chapter 4: Implementation presents the implementation of the five NOLAS Insights prototypes. A system overview is given of the final prototype.

Chapter 5: Results presents the results from the data generation methods used in each prototype evaluation.

Chapter 6: Discussion revisits the desired system properties, discusses the validity of the results, and presents the main findings related to the research question.

Chapter 7: Conclusion presents a conclusion of project and briefly describes possibilities for future work.

Chapter 2

Theory

The goal of this chapter is to present key concepts in interaction design, user-centered design (UCD), prototyping, and system evaluation. Together these concepts form a theoretical framework that supplemented the research method that was used in this project. The value of NOLAS Insights is highly dependent on the usefulness and usability of the system, and it is therefore important to understand the implications of the design.

2.1 Interaction design

(Preece et al., 2015) defines interaction design as ”designing interactive products to support the way people communicate and interact in their everyday and working lives”. It does not define any strict framework to follow, but is concerned with the practice of utilizing different frameworks, techniques, and methods to design a good user experience. (Thackara, 2001) describes how humans are great at technological development, but have limitations when it comes to understanding people and figuring out the need for the new technology that is entering the world. Interaction design has therefore been an important part of innovation in recent years, and will continue to be so in the future.

(Saffer, 2010) says that ”interaction design is about behavior, and behavior is much harder to observe and understand than appearance”. Saffer continues by emphasizing the non-strict nature of interaction design and considers it to be art. He says ”it is by its nature contextual: it solves specific problems under a particular set of circumstances using the available materials”, implying that a product does not last forever, but it is made to serve a particular time and context. An important aspect of interaction design is to understand these circumstances, the *context of use*.

2.1.1 Human-computer interaction

Human-computer interaction (HCI) is a field of research that focuses on the design and use of computer systems, and how humans interact with these systems. It can be considered a combination of different areas of science, where computer science and interaction design are the most central. The purpose of HCI is to provide methods and guidelines to ensure high *ease-of-use* in systems, with intuitive user interfaces that enhances good experiences and reduces bad experiences. HCI is a more narrow term than interaction design and most research of the present study will relate to HCI concepts, but is supplemented by general design theory. Since there is no agreed upon definition of HCI, ACM[1] defines a working definition as ”a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them” (Hewett et al., 1992, p. 5). The phrase ”and with the study of major phenomena surrounding them” implies that HCI in itself is a broad term that involves many different disciplines. In this thesis user-centered design, usability testing, and the user experience is important.

2.1.2 The user experience

The user experience (UX) is a core part of interaction design, and is connected to every branch of the broad term. Norman and Nielsen summarizes the definition of UX as something that ”encompasses all aspects of the end-user’s interaction with the company, its services, and its products” (Norman and Nielsen, 2016). They also stress the need for separation of the broader term ”total user experience” from user interface (UI), in which usability is a quality attribute according to (Nielsen, 2016). For example, consider a music service. The service provides great UI for finding, playing, and organization of songs, but the UX might be poor if the library of songs is limited. The UI has big impact on the UX, but other factors are also important. Norman and Nielsen lists some of the requirements to make an exemplary UX:

1. Meeting the exact needs of the customer.
2. Go beyond what the customers say they want.
3. High-quality UX requires seamless merging of multiple disciplines, including engineering, marketing, graphical and industrial design, and interface design. (Norman and Nielsen, 2016)

The requirements reflect the important role of the designer when creating a customer-specific product, as meeting and exceeding the needs of the customer requires a thorough understanding of the user perspective. Hassenzahl summarizes this understanding by saying ”UX is a consequence of a user’s internal state (needs, motivations, etc.), the characteristics of the designed system (usability, functionality, etc.), and the context within which the interaction occurs” (Hassenzahl and Tractinsky, 2006). This is important to keep in mind in all iterations of development to ensure a good UX.

[1] https://www.acm.org/

2.1.3 The process of interaction design

According to (Preece et al., 2015) the process of interaction design is defined by the following four basic activities:

1. **Establishing requirements**: The requirements of the system are defined.
2. **Designing alternatives**: Alternative designs are made that meets *some* of the requirements.
3. **Prototyping**: A prototype is made from the design alternatives in increasing detail.
4. **Evaluating**: The prototype is evaluated by its success in meeting the original requirements.

The start of a project generally involves establishing initial requirements in order to solve the problem. This is followed by brainstorming design alternatives to fulfill the requirements. The new design alternatives might require changes to existing requirements or establishing new ones. After the alternative design, the next step is prototyping. The level of detail in the prototypes increases as the project progresses. They might start off as something simple like a paper prototype. The prototypes are evaluated with the goal of ”Eliciting responses from potential users about what they think and feel about what has been designed, in terms of appeal, touch, engagement, usefulness, and so on, can help explicate the nature of the user experience that the product evokes” (Preece et al., 2015, p. 15). A usual approach to this is usability testing, a process influenced by methods originating in the fields of software engineering and HCI.

2.1.4 Context of use

The *context of use* represents the environment and conditions the system is used in on a daily basis. Involving users early is a key factor to get an understanding of the perspective of the user. This understanding highlights the most valuable aspects of the product. Knowing the *context of use* is critical when it comes to requirement engineering, as faulty and missing requirements comes at a high cost. After the requirements are set, prototypes can be made. In prototype evaluation it is important that the data is gathered in *context of use*. This ensures higher ecological validity, which is explained in section 2.4.

2.2 User-centered design

User-centered design is defined in (ISO 9241-210, 2010) as ”an approach to interactive system development that focuses specifically on making systems usable”. It is a multidisciplinary activity”. The UCD process builds on the interaction design process by including the user in every stage of the process. The user is already involved when the requirements are being established and continues to take part in the process. This increased focus on involving the user is important in regards to the *context of use*. (Abras et al., 2004) says that UCD is ”a broad term to describe design processes in which end-users influence how a design takes shape”. This means that UCD can involve multiple methods and does not necessarily follow one process. The important part of the design process is the user involvement. (Abras et al., 2004) highlights two examples:

1. Consulting users about their needs and involve them at specific times during the design process, typically during requirements gathering and usability testing.
2. Methods in which users have a deep impact on the design, by being involved throughout the design process.

These design process approaches focuses highly on the user’s interpretation of the system, and how the users perceive and interact with the system. However, they require a lot of user input. To get appropriate user input the user group of the system must be defined, and a strategy to involve them must be created. Lastly, a test approach is needed get helpful and relevant feedback.

2.2.1 UCD process

The UCD process improves upon the simple interaction design process, by making it more specific, technical, and user-oriented. The general phases are:

1. Identify the need of the customer. What problem is the innovation solving.
2. Specify the context of use to ensure high ecological validity.
3. Specify a set of requirements for the system that needs to be solved.
4. Produce design solution to solve the requirements made in the last step.
5. Evaluate the designs that were produced in the last step by testing in the context of use.

The UCD process visualized in figure 2.1 is inspired by usability.gov[2], and shows how the different phases relate. The UCD process is usually incorporated into or combined with other software engineering processes to make a development approach.

2.2.2 Advantages and disadvantages of UCD

The major advantage of UCD is the ability to satisfy the customer’s needs, achieved by frequent exploration of the customers’ goals and thinking process. (Abras et al., 2004) explains the awareness as ”a deeper understanding of the psychological, organizational, social and ergonomic factors that affect the use of computer technology emerges from the involvement of the users at every stage of the design and evaluation of the product”. By testing in the context of use you ensure robustness, efficiency, and usually an effective system.

[2]https://www.usability.gov/what-and-why/user-centered-design.html

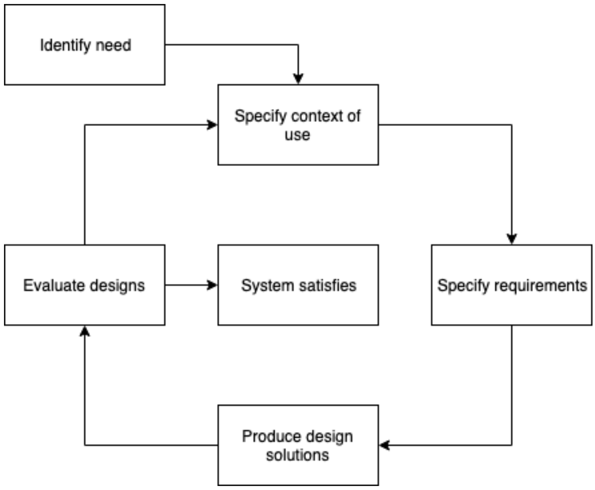

Figure 2.1: General phases of the UCD process.

UCD also affects the customer's expectations and satisfaction with the product. The process involves multiple iterations, which lets the users get a feel for the product over time. The high user involvement throughout the development makes the expectations of the product more realistic. It also increases the ownership and satisfaction with the product, and can make delivery of the product smoother.

The major disadvantage of UCD is the cost of the customer involvement. The process requires human, financial, and time resources to gather the necessary data. The context of use must be explored, and several prototypes must be made and tested appropriately.

Ideally the UCD process includes a multidisciplinary team, ”particularly psychologists, sociologists, and anthropologists whose job it is to understand users' needs and communicate them to the technical developers in the team” (Abras et al., 2004). The needs of the users are hard to understand, and are always easy to translate into a design. When the users do not get what they want, they might get displeased with the system or become frustrated with the designers. This can be challenging, and stresses the need for openness and good communication throughout the process.

(Abras et al., 2004) also states the problem of general use. The users might have a lot of personal and specific requests that might make the product too specific to be used by other clients. This also affects the cost of the product. According to a survey conducted by (Vredenburg et al., 2002), involving over a hundred UCD practitioners, ”cost-benefit tradeoffs play a major role in the adoption of UCD methods”. This claim is backed up by the fact that field studies were ranked highly important, but is used infrequently because of the method's cost.

2.3 Prototyping

Prototyping is a key concept in interaction design and is vital in the UCD approach, as the prototypes allows certain functionality to be tested. A prototype is different from the final product and provides a way to test different approaches to features and functionality over multiple iterations. The system should improve for each prototype evaluation, which is why an iterative development approach is most commonly used with UCD (Vredenburg et al., 2002). Each iteration usually involves an attempt to achieve some kind of goal within a given time frame. After the iteration is done it can be tested, preferably in the context of use, and the features can be evaluated to guide the approach in the next iteration.

In usability engineering it is normal to separate horizontal and vertical prototyping. Horizontal prototyping focuses on a broad set of features with lower level of functionality, while vertical prototyping focus on the details of specific features (Nielsen, 1994b).

(Gulliksen et al., 2003) stresses the importance of starting out with low-fidelity prototypes in order to test broad concepts about the system. Examples of such prototypes are paper-based prototypes, digital mock-ups, scenarios, and storyboarding. Balsamiq[3] is a digital tool for rapid prototyping. It is superior to paper-prototypes as it allows the user to navigate around, giving it a more authentic feeling. Low-fidelity prototypes are really useful because of how cheap and quick they are to produce and modify (Preece et al., 2015).

After gaining general knowledge about the system, the fidelity of the prototypes can be increased. High-fidelity prototypes increase the functionality of low-fidelity prototypes and starts to show how a system might actually look as a final product. Iterations of prototype evaluation will establish new user needs, technical issues, and usability problems. Prototyping can be done by using existing technology or creating new. The prototypes can be produced quicker and cheaper if they use fake data (Nielsen, 1994b). A prototype using fake data is still able to convey the potential of the product to the user. Every prototype is a compromise between horizontal and vertical functionality, and as the iterations approaches the final product the level of fidelity increase.

2.4 System evaluation

The people who leads evaluations of the system are referred to as evaluators. They are crucial to the design process, and according to (Preece et al., 2015) they ”collect information about users' or potential users' experiences when interacting with a prototype, an app, a computer system, a component of a computer system, an application, or a design artifact such as a screen sketch”. The evaluator focuses on multiple aspects of a system, including usability and the UX (see 2.1.2).

The system can be evaluated in different phases of the development, ranging from low-fidelity prototypes to nearly finished systems. The evaluation commonly establishes whether requirements of the system are fulfilled. An iterative development approach allows the

[3] https://balsamiq.com/

evaluators to get input frequently throughout the project. The feedback from the evaluations leads to design improvements in later prototypes which is then subsequently evaluated (Preece et al., 2015).

2.4.1 Usability testing

According to the nngroup[4] usability is ”a quality attribute that assesses how easy user interfaces are to use” (Nielsen, 2012). Nielsen defines five quality components:

1. Learnability
2. Efficiency
3. Memorability
4. Errors
5. Satisfaction

The nngroup separates utility and usability, and names the combination of these *useful*. During the creation of an information system, usability is a highly valued attribute. Multiple studies investigate how design choices affects the usability. (Davis, 1993) investigated the technology acceptance model (TAM) and found that the *perceived usefulness* was 50% more influential than the *ease of use* in determining how much a new system is used. This implies the need to establish and develop useful functionality. Both Preece and the nngroup define utility as ”whether it provides the features you need”, whilst usability is concerned with how pleasing these features are to use.

Usability can be measured by the five quality components listed above. Learnability seeks to answer how easy it is for beginners of a system to perform basic tasks. Efficiency relates to how quickly an experienced user can perform more advanced tasks. Memorability is how fast they can relearn the system after being gone for a while. Errors is a bit more open task, and the evaluator seeks to answer what errors are happening, their severity, and how difficult they are to fix. Satisfaction is simply how satisfied the users are with the system. The combination of these components defines the usability of a system, and is therefore important to test and evaluate to make good systems. That is why usability testing is a very common practice among designers, and important in the present thesis.

There are several methods to test usability, but the most common is by doing regular user testing. Testing is done in the context of use, and involves observing users performing tasks designed to test various parts of the system. It is useful to test prototypes with varying level of fidelity; from sketches to nearly finished products. That way you get important feedback during the development of the product.

There are also practical concerns of usability tests, like location and the number of participants. The location will vary depending on who the designers and users are. For small companies a regular office or conference room is enough. The nngroup claims that the best number of users is five when considering the cost of the usability testing (Nielsen, 2000),

[4] https://www.nngroup.com/

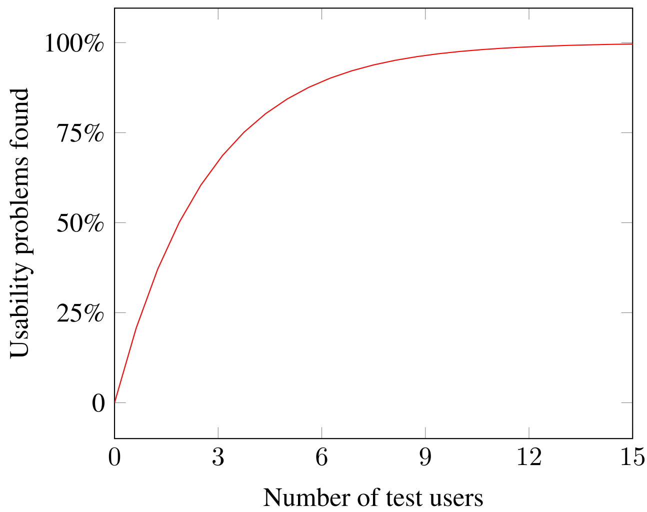

Figure 2.2: The number of usability problems found in relation to the number of test users according to (Nielsen, 1994a).

as 85% of the usability problems are estimated to be found. This is based on research done by Jakob Nielsen and Tom Landauer, where they found the correlation between the number of discovered usability problems and users to be: $N(1-(1-L)^n)$ (Nielsen, 1994a). N is the total number of usability problems, n is the number of users, and L represents the proportion of problems discovered when testing the average user. The study found L to typically be around 31%. The function converges towards a saturated state, implying that increasing the number of users has diminishing influence on the results. The function is displayed in figure 2.2.

2.4.2 Interpreting the data

The data gathered in evaluation of a system is only useful if it is interpreted correctly. The type of research influences how the interpretation should be done, and it is important to assess the quality of the data. (Preece et al., 2015) mainly focuses on five terms that are important in regards to data interpretation:

Reliability is defined by how well the test produces the same result if the method is performed in the same way by another evaluator. This will vary depending on the type of evaluation that is being done. A controlled setting involving users will be much more reliable than a natural setting involving users. In a controlled setting the evaluator can define a strict process to follow and have more control of the variables, but a natural setting is more random and unpredictable.

The **validity** of a test is concerned with the relation between what the test is measuring in reality and what it is designed for. The researchers produce the data through observation, and the data cannot always be trusted. The validity is grouped into internal and external validity.

Internal validity is concerned with how applicable the findings are to answer the research question. Some causes of concern in internal validity are:

- Repeated testing: The results might be affected by the fact that multiple subjects are testing the same system multiple times.
- Interviewer bias: The interviewer might be asking leading or primed questions, which will cause the respondent to answer in a specific way.
- Selective recall: A person might remember certain things that they feel are important, and forget other things that are equally important.
- Selective perception: A person notices certain things, but fails to notice other things. Similar to selective recall.
- Accentuated perception: Because of historic or newer experience an observer might be more sensitive to certain things, and will because of this do observations that other observers might miss.
- History: Events outside of the testing, or in between the iterations of testing, might affect the results.
- Maturation: The time factor might affect the results. Participants might change over the course of the testing.
- Ecological validity: Affects the results by the environment in which the testing takes place. Testing outside of the natural environment, for example in a controlled setting, might lower the ecological validity. The results might also be affected by the fact that the users know they are being observed.

External validity is concerned with the scope of the research, and whether the results can be generalized. Some causes of concern in external validity are:

- Dependency of a certain user group: Results gathered through experiments done with a specific user group, might not generalize to the rest of the population.
- Non-relevant users: It is important that relevant users are tested to ensure valuable data.
- Non-relevant test case: The tests that are used in the experiment must be designed with the purpose of being similar to use cases in real life.
- Not enough participants: If there are not enough participants to test, the results might be statistically bad and not be able to give any solid insights.

Ecological validity is a sub-component of external validity, and is concerned with how the evaluation is influenced by the environment in which it takes place. It is a measure of how good experiments translate into real world settings. Low ecological validity in a test is indicated if it does not translate well into the real world. A controlled setting usually takes place in a laboratory, and the people being tested might not be acting naturally in a test environment. The fact that the subjects are aware of being studied affects the ecological validity (Preece et al., 2015). This is similar to the placebo effect in medical research. The placebo group of patients are given false medicine, but often show some kind of medical improvement due to the belief they are treated by an effective medicine.

Bias is a distortion of the results, which is an inevitable human error. It is impossible to be entirely objective. Bias affects both the interviewer and the participant. The interviewer might infer his bias by the way he asks his questions, his facial expressions, or his reactions to answers of the participants. The interviewers themselves might also be biased in what they observe. This is especially important to think about in the observer role. The observer might ignore important details because of lack of interest in them. The biases are therefore important to keep in mind when constructing and performing any kind of user testing.

Scope explains to what degree the findings of the study can be generalized, that means it can be used as knowledge by other designers and evaluators when creating or modifying another product. When creating a product for a specific group of people, to be used in a specific setting, the scope is often quite narrow. Still, it might be possible to establish generalized findings from the data.

Chapter 3

Research method

This chapter presents the research methods used in this project, with inspiration from the theoretical framework presented in chapter 2. The research methods define a strategy to answer the research question, by guiding the development and evaluation of NOLAS Insights. The evaluation of NOLAS Insights involves data generation, and the methods used to do so are described. Lastly, the chapter presents ethical and practical issues of the project.

Oates' model of research (Oates, 2006) was used as a guideline to define the research process in the present project, and figure 3.1 highlights the chosen methods. Design and Creation was chosen as the main research strategy, with inspiration from user-centered design (UCD). The data generation methods consist of interviews and observations, and the resulting data is analyzed qualitatively.

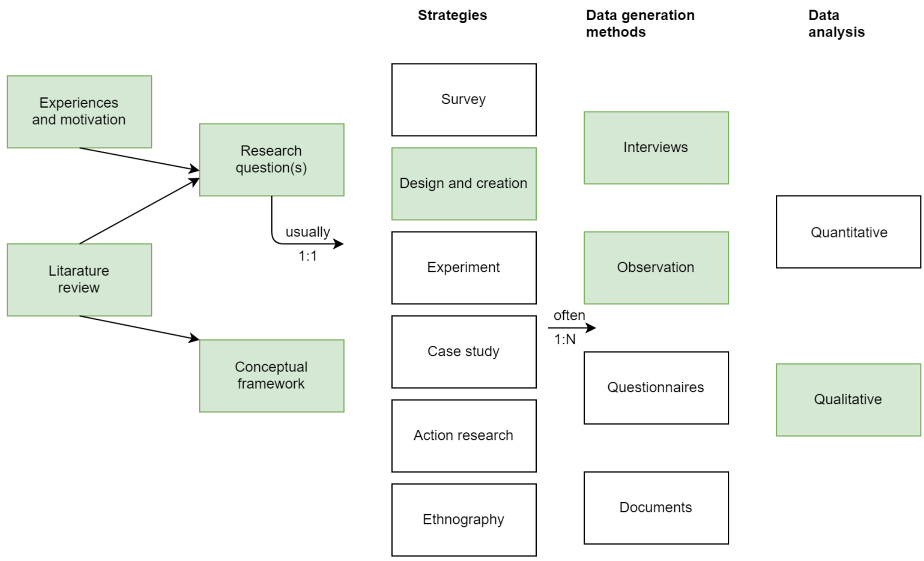

Figure 3.1: Oates' research model (Oates, 2006). The methods used in the project are highlighted.

3.1 Research strategy: Design and Creation

The Design and Creation strategy aims to develop some sort of new IT product, also called an *artifact*. An artifact is normally defined as a system that solves some kind of problem. The problem can either originate in a specific organization or be a general problem in society. What an artifact really represents is one or more pieces of contribution to knowledge, and (March and Smith, 1995) limits this to:

- **Constructs**: Language of concepts, characterizing phenomena, like in natural sciences.
- **Models**: Combining constructs to describe tasks, situations, or artifacts.
- **Methods**: Ways to perform goal-directed activities. More commonly called software methodologies today. Relates to the process to follow during software development.
- **Instantiations**: The final product in which all the foregoing concepts have been merged to create a computer system.

The main goal of the Design and Creation strategy is to create the artifact, unlike other strategies which focus more heavily on gaining theoretic advances. In (March and Smith, 1995) it is described as "Rather than posing theories, design scientists strive to create models, methods and implementations that are innovative and valuable.".

The work in this thesis follows the Design and Creation principles with the goal of creating an information system called NOLAS Insights. The system is based on the desired system properties described in 1.5. The Design and Creation strategy uses an iterative process involving five steps, similar to the UCD process. (Vaishnavi and Kuechler, 2004) defines these steps as awareness, suggestion, development, evaluation and conclusion. Next, each of these phases will be explained more in depth.

3.1.1 Phase 1 - Awareness of the problem

The awareness phase revolves around trying to understand a problem. The idea of NOLAS Insights was proposed by an air emergency doctor and was further inspired by the managers of Norwegian Air Ambulance (NAA). Its purpose is to solve the problem of giving the management team an operational overview. The output of the awareness phase is a formal or informal proposal for a new research effort. After meetings and discussions with supervisors and stakeholders an informal proposal was made. This proposal is listed in figure A.1.

3.1.2 Phase 2 - Suggestion

The second phase follows directly from the initial proposal and usually involves some kind of prototyping that transforms abstract concepts into a real artifact. The prototype can be made in various ways, with varying degrees of fidelity. This simplified version of the final product can be made through regular development, with prototyping software or simply be made on paper. The prototype offers a way to suggest how certain functionality should work and the general look of the product. The importance of prototyping is described in section 2.3.

The first tentative idea for NOLAS Insights was proposed by NAA, by sketching the product on paper. Figure A.2 shows one of the sketched pages, and together the sketches form a conceptual design. The conceptual design outlines desired features, the types of data needed, and possible ways to design the product.

3.1.3 Phase 3 - Development

The development phase consists of developing and incorporating findings from the suggestion phase. This involves the construction of an artifact, but the artifact does not necessarily need to be a software system. (Vaishnavi and Kuechler, 2004) gives the example of creating an artifact by constructing a mathematical proof of the application of an algorithm.

An iterative development approach was chosen to increase the user satisfaction, and benefits from the ability to make prototypes with different goals. In the start of the project a low-fidelity prototype was made to establish broad concepts with low effort. For each iteration thereafter, the fidelity of the prototypes was increased. In the early awareness

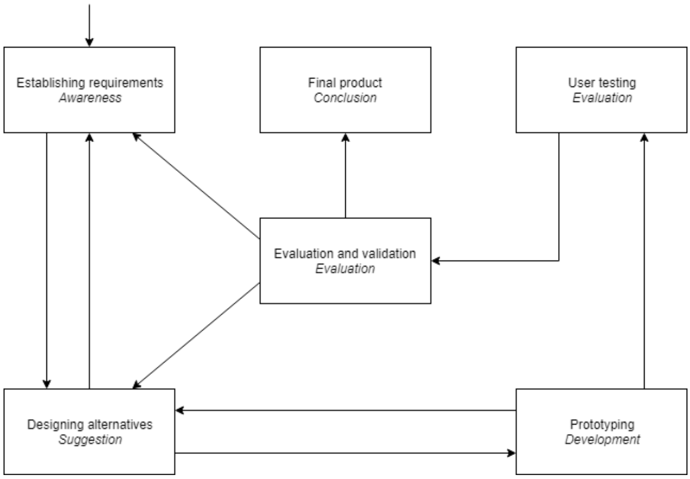

Figure 3.2: Iterative development approach for developing NOLAS Insights.

phases it was established that NAA preferred a few well-working features compared to many suboptimal features, which led to an increased focus on vertical prototyping.

3.1.4 Phase 4 - Evaluation

When an artifact is developed it needs to be evaluated in order to determine its value. The constructed artifact is evaluated according to the criteria set in the proposal from the awareness phase. Deviations from expectations, both quantitative and qualitative are carefully noted and must be tentatively explained. ”That is, the evaluation phase contains an analytic sub-phase in which hypotheses are made about the behavior of the artifact” (Vaishnavi and Kuechler, 2004). Before the evaluation starts, a set of hypotheses about the system behavior must be made. The desired system properties described in section 1.5 defined the behavior of NOLAS Insights informally.

The goal of the evaluation revolves around determining the extent the hypotheses are realized in the artifact. If the evaluation implies any issues they can be addressed by redoing the suggestion phase. The evaluation in this project thesis is based on the data gathered from user tests and the interviews. There were five user test sessions, each tested and evaluated by relevant users of the system. Observing the users during the usability tests, and conducting interviews afterwards were suitable ways of gathering data to answer the research question. The data is qualitatively studied to propose changes and to discover new need for the system. Theory related to system evaluation is described in 2.4.

3.1.5 Phase 5 - Conclusion

This phase concludes the research and states the contributions of the project. The finalized constructs might deviate from the initially proposed requirements, but should be considered satisfactory as a specific research effort. The results from the evaluation phase are presented in chapter 5 and discussed in chapter 6.

3.2 Data generation

A big part of the Design and Creation strategy revolves around generating data in order to analyze it. The analysis is needed to measure the strengths and weaknesses of a product. All research strategies contain one or more methods to generate data. In order to collect data from the management of NAA, a relatively small group of people, interviews and observations was used. Quantitative was deemed inappropriate due to the small number of users taking part in the evaluations. These techniques supply empirical data that makes it possible to qualitatively study the artifacts of the projects.

Five meetings were held monthly in Oslo with participants from the management team of NAA starting in December 2018. These meetings discussed the current state of the project, ideas for future development, tackled important concerns, and other relevant topics. After the meetings, one-on-one sessions were held with a selection of the stakeholders to gather empirical data through the chosen data generation methods. The number of participants varied from four to five people. The participants were a part of the management team, which represents the user group the system is made for. The aim of the one-on-one sessions is to observe users during a usability test, and to collect their thoughts about the current implementation, new creative ideas, and other interesting thoughts in a semi-structured interview after the usability test. All of the sessions were audio recorded to increase the validity of the collected data, in regards to researcher recall bias. A researcher might only remember certain things that he wants to remember, and in a specific way that might not be true. In total, there were held 21 usability tests and 13 interviews.

3.2.1 User session setup

The user session setup stayed consistent in the evaluations of the prototypes, and is visualized in figure 3.3. The same room, equipment, and positioning of people was used throughout the iterations. The moderator was positioned next to the participant, and guided the subject through the user tests and interview. The observer was positioned at the other side of the table and took notes throughout the session. The computer used by the participant was connected to a big screen to let the observer see what the participant was doing.

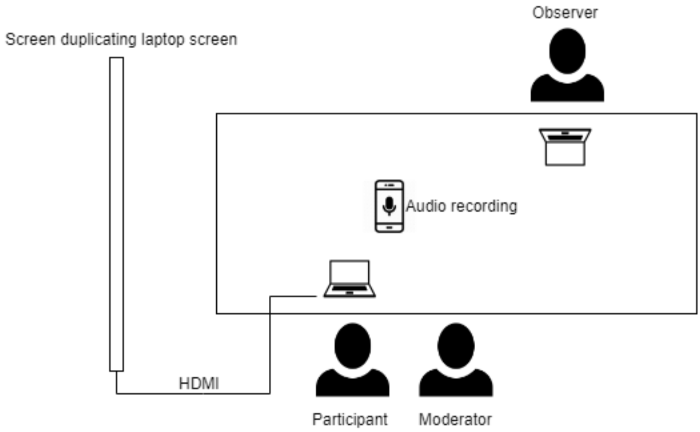

Figure 3.3: The user session setup for the evaluations of the prototypes.

3.2.2 Usability testing

Usability testing determines the ability of a group of people to utilize functionality in a system. Generally, this is done by asking the users to complete a set of tasks while they are being observed. This includes both simple and hard tasks, and are meant to give insight into good and bad implementation of features in a system. More theory regarding usability testing can be found in section 2.4.1.

NOLAS Insights will be used by one user group, and user testing this specific group is therefore critical. Everyone in the management of NAA are of course different, but as a group they share similarities. By user testing a big subset of the group, a profile regarding their abilities and use of the prototype can be created. The profile can be used in many ways, for example, when deciding how easy a feature needs to be to use.

The tasks were designed to test the new and updated features of each prototype and was designed to represent real use cases for the NAA management. The users were evaluated through their attempt at accomplishing each task. Each task creates valuable data by observing successful and unsuccessful approaches to tasks and listening closely and objectively to the user. The user test data is then qualitatively analyzed to aid in the answer of the research question and to improve NOLAS Insights.

3.2.3 Interviews

Each user test is followed by a *semi-structured* interview to gather empirical data. A semi-structured interview consists of a set of predefined questions with the possibility of exploring other related themes that arise in the interview. This allowed for the necessary information to be collected, as well as following up on creative ideas proposed by the participants. Interesting information include the users' perception of the system, what they think is important, and how they generally feel about the system. The users can highlight what the system is lacking and suggest improvements. It is very common to combine interviews with observation-based techniques like usability testing as the data from the methods supplement each other. According to the nngroup, it is important to wait until the end of the usability test to interview the users. ”If you ask questions before the participant tries to perform tasks with your design, you will have primed the user to pay special attention to whatever features or issues you asked about.” (Pernice, 2018).

The interviews that were conducted with the management of NAA were qualitatively studied to gain insights into concepts about the design and usefulness of the system, as well as insight into the organization as a whole. They clarified what was good, what was bad, and what the focus should be going forward. The interviews helped the researchers understand the user group, improve NOLAS Insights, and answer the research question.

3.3 Ethical issues

Some ethical issues were discovered before the data gathering process started. There is usually a concern of gathering data from users as the sensitive data needs to be protected, especially in regards to the new General Data Protection Regulation[1] (GDPR). The use of data from user tests and interviews had to be documented and approved. To start this process an application detailing the use of the data was sent to the Norwegian Centre for Research Data (NSD). The application was approved in January 2019. An important part of the data gathering is to let the participant know that they always can withdraw from the project at any time or ask to see the information stored about them. Before each user test, every participant was asked for their consent to be audio recorded, and was informed that all person specific data, like the recordings, would be deleted at the end of the project, or earlier if they made a request. The names of the participants and the results of the user testing were kept in storage on different machines, a requirement from NSD.

3.4 Practical issues

The large emphasis on usability in this project requires multiple user tests and interviews, a time-consuming effort. There is only one user group, and managers have busy schedules. This poses a challenge for scheduling meetings and user test sessions. Nevertheless, NAA managed to supply users every month until the project’s end, leading to five evaluation iterations. The length of the sessions were reduced to attract as many participants as possible.

NOLAS Insights extracts data from NAA’s database system NOLAS, and this database contains sensitive data that must be kept secure. Both in regards to protecting the big amount of data in NOLAS, and outsiders being able to identify treated individuals through combination of data. A direct extraction from NOLAS was deemed inappropriate after a

[1](Council of European Union, 2016)

discussion with IT experts and the management of NAA. Instead, only the necessary data was made available for extraction to NOLAS Insights. The careful selection of extractable data gave NAA better control in the event of a security breach of NOLAS Insights. Under such circumstances NAA would know what the compromised data was, and could remove the system's access to extractable data. An additional measure NAA can take when the system is in production is to limit the access to users on a set of verified IP addresses.

A consequence of the data extraction approach was the dependency on assistance from NOLAS developers. In an old system like NOLAS, experience with the system is important. The researchers needed to collaborate with NAA's developers to design the structure of the extractable data, understand it, and update it as new needs for data arose.

Chapter 4

Implementation

This chapter presents the implementation of the four initial prototypes and the final version of NOLAS Insights. The system was made with the purpose of converting operational data into useful information and visualizing it intuitively to the management of Norwegian Air Ambulance (NAA). Changes to design and functionality are presented for each iteration. Each prototype iteration lasted approximately one month. Lastly, a system overview is given of the final prototype. Instructions to try a demo of the final prototype can be found in appendix B.5.4. The screenshots of the prototypes are included with permission from NAA.

4.1 Tools and frameworks

NOLAS Insights is built on the web development stack called MERN, which divides the system into a frontend and backend. The name MERN comes from the use of MongoDB, ExpressJS, React, and NodeJS.

The frontend is built with React, which promotes a modular structure of components. Usually components in React pass state between child and parent in a hierarchy, but Redux was used to easily share data across components. To style these components quickly, the design framework Semantic UI[1] was used. Semantic UI includes styling of common design components like buttons, dropdowns, and tables. The chart library called Recharts was used to create the operational visualizations as the library allowed smooth transitions between graphs and supported customization and different graph types.

The backend of NOLAS Insights consists of NodeJS, ExpressJS, and MongoDB. NodeJS is a JavaScript runtime system which uses npm as its default package manager. npm works for both the frontend and backend and contributes with packages that provide certain logic that is commonly needed in applications. In NodeJS there are multiple web frameworks,

[1]Semantic UI: https://semantic-ui.com/

but ExpressJS is the most popular. It controls the routing to pages, caching, and the content that the user is presented on the web page and was chosen due to its robustness and the low amount of code required to do simple tasks. MongoDB is a non-structured query language database, which stores data in collections. The non-relational system provides the necessary functionality necessary for storing data in NOLAS Insights and is well integrated with the other frameworks in the MERN stack.

4.2 Prototype I

The goal of prototype I was to get early feedback on a simple version of the system based on the key lessons learned in the preliminary study. The problem that the system should solve was explored through informal meetings with supervisors of the project and with NAA. These discussions led to an initial project proposal, and NAA made a conceptual design sketch of what they expected the system to be like. A needs-analysis document was also created and deemed the development of NOLAS Insights to be feasible. These artifacts are listed in appendix A, and all screenshots of the prototype can be found in appendix B.1.

Prototype I is a simple, graphical mock-up made using Balsamiq[2], which is a rapid wireframe-making tool used to quickly deploy low level prototypes. The look of the Balsamiq prototypes is simple and paper-like and promotes discussions about structure and content instead of color and style. The tool offers drag-and-drop placements of common user interface elements and lets the user navigate between screens by clicking on elements like buttons. Together this simulates a web page.

4.2.1 Design

Prototype I introduces core design ideas about the system structure of NOLAS Insights and contains a navigation menu, a dashboard, and a layout for operational performance. Figure 4.1 shows the proposed home page dashboard of NOLAS Insights. The page shows a customizable selection of key operational statistics about NAA's operations and the most important trends. A detailed trend view is shown in figure 4.2, where each trend has a link to the graphical explanation. The menu header at the top shows the available pages in NOLAS Insights, and the *Mission*, *Contingency*, *Security*, and *Miscellaneous* pages contain different graph types shown in the operational performance layout.

[2] https://balsamiq.com/

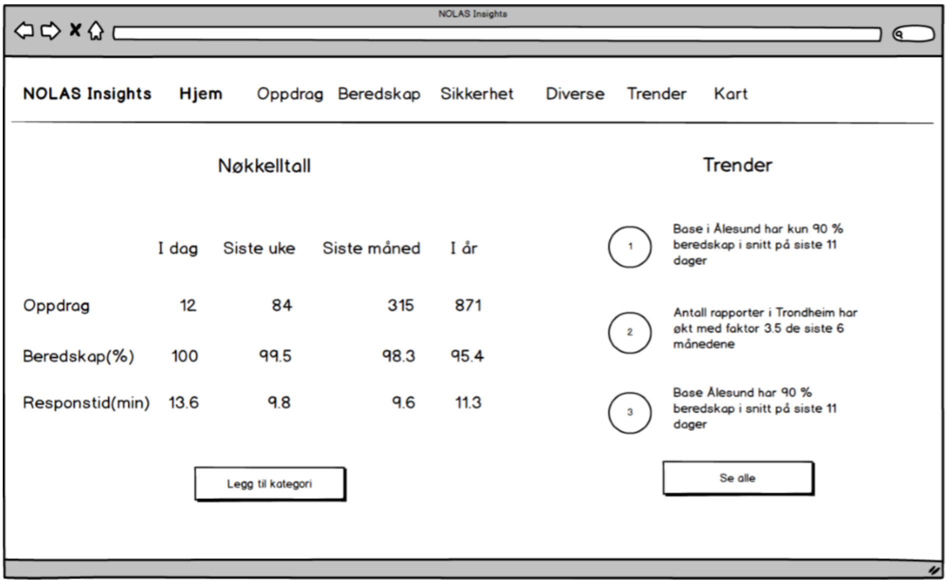

Figure 4.1: Prototype I - Home screen with key statistics and trends.

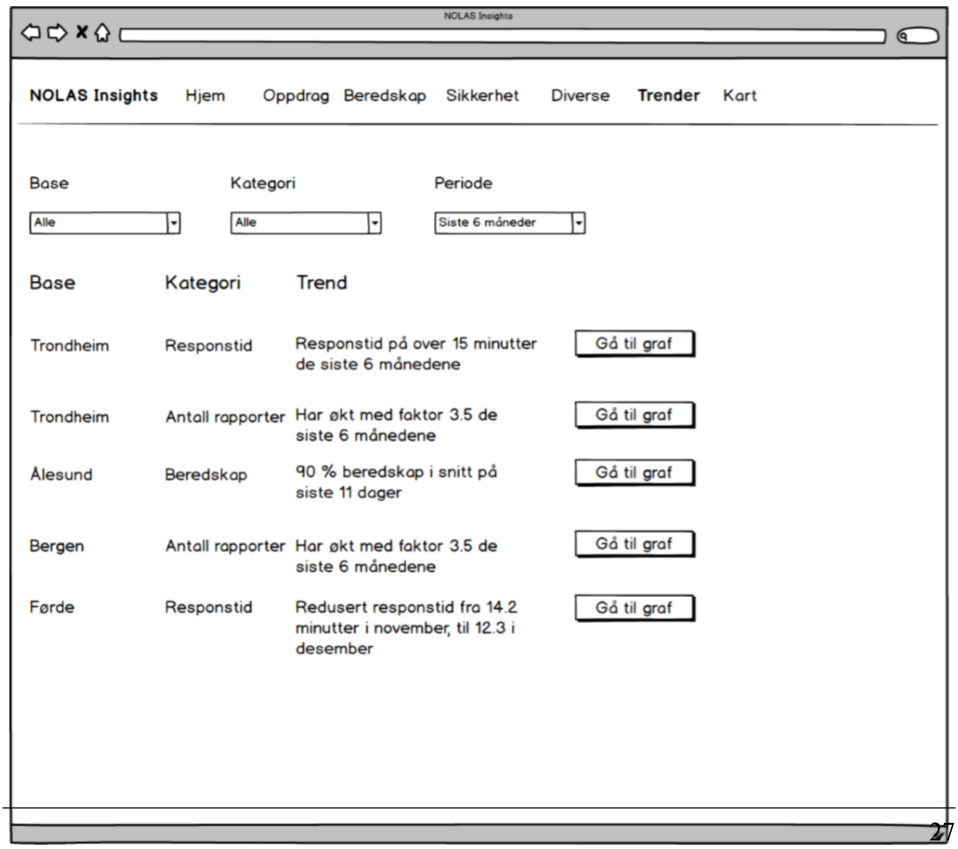

Figure 4.2: Prototype I - Trends grouped by category and the base they originate in.

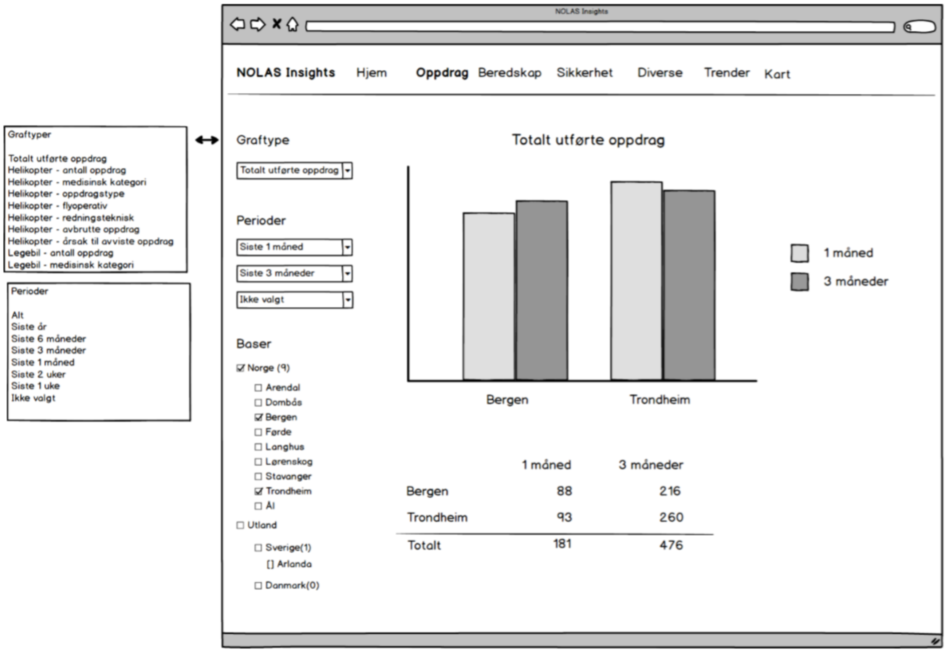

Figure 4.3: Prototype I - Missions. The image shows a comparison graph of executed missions in Bergen and Trondheim.

The operational performance layout for *Mission* is shown in 4.3. Filters on the left on the page indicate different choices the user can make to change the visualized data. This includes the graph type, selection of bases, and type of periods. The boxes on the left indicate the dropdown alternatives for the graph type and period filters. The remaining part of the layout visualizes the operational characteristic with a graph and a table. The graph shows data for multiple periods and bases.

While the graph gives a quick visual overview of the operational performance, the goal of the table beneath is to provide a numerical representation. The table in figure 4.3 can be used to identify values for individual bases or aggregated values for the base selection. If all the Norwegian bases are selected, the total number of missions executed can be identified in the selected period.

4.2.2 Functionality

Prototype I made user interaction possible with clickable elements that linked to different pages. Each page in prototype I is made with a drag and drop interface, making it unfeasible to create representations for all of the filter configurations. One page was made for each menu item, and a few additional screens were made to demonstrate the use of the base filter for the tasks in the user test. Some of the functionality can be simulated;

for example, when a user clicks the graph-type dropdown in the filters of the operational performance layout. Instead of having a list appear when the dropdown is clicked, the test leader can explain what the user should expect to see.

4.3 Prototype II

The most important goal of the second prototype was to transform the first low-level prototype into a high-level web-site prototype that could facilitate discussion about the intuitiveness of graphs. To speed up the development, the prototype was built on top of a tutorial application[3] showcasing the MERN stack by building a shopping list application. All the data used in the prototype is fake. See appendix B.2 for more screenshots.

4.3.1 Design

Prototype II introduces the first web page implementation of the dashboard, operational performance layout, and trends. Figure 4.4 shows the navigation menu and the operational performance layout consisting of filters, a graph, and a table component. The navigation menu structures the system and groups it into *Dashboard*, *Mission*, *Contingency*, *Security*, *Miscellaneous*, *Trends*, and *User Profile*. The dashboard design can be seen in figure 4.5, and figure 4.6 shows the *Trends* layout.

The design is similar to prototype I but differs in a few areas. The dashboard is accessed by clicking NOLAS Insights instead of clicking *Home* (now removed), and the *Map* page is discontinued. Additionally, a user page and log out button were added.

The graph is implemented with the graph library Nivo[4]. Nivo allows for smooth transitions between different graphs, for instance, when a new base is checked or the graph type changes. The support for multiple data sets was required in order to satisfy the need to compare multiple bases over multiple periods. When the user hovers a data set, a tooltip is shown with information about the associated base and data-point value.

4.3.2 Functionality

The functionality in prototype II is still reduced but offers more than before. The user is able to interact and change what they see by selecting different graph types and changing the selection of bases. Figure 4.4 indicates that the graph type is selected in a dropdown while checked off bases are displayed in the graph. As the data were hardcoded, they were only available for three bases. Unavailable bases and graph types were visible but had transparency to indicate a disabled state. Due to time constraints, the period filter was

[3] Learn the MERN Stack by Brad Traversy: https://www.youtube.com/watch?v=PBTYxXADG_k&list=PLillGF-RfqbbiTGgA77tGO426V3hRF9iE&index=1

[4] Nivo: https://nivo.rocks/

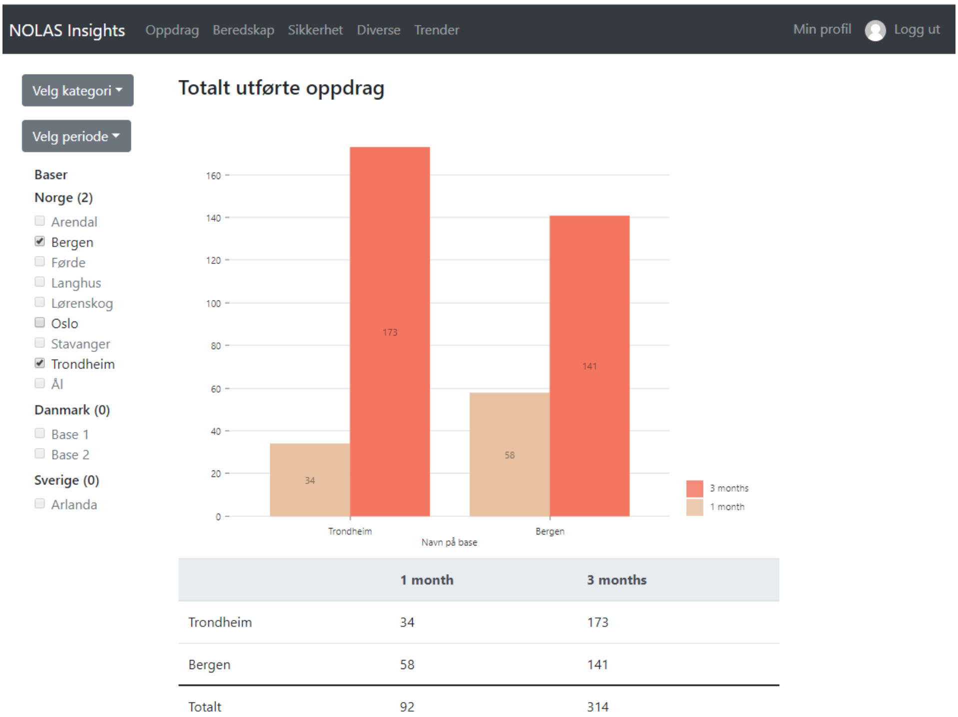

Figure 4.4: Prototype II - the operational performance layout showing the number of missions executed at two bases in different periods.

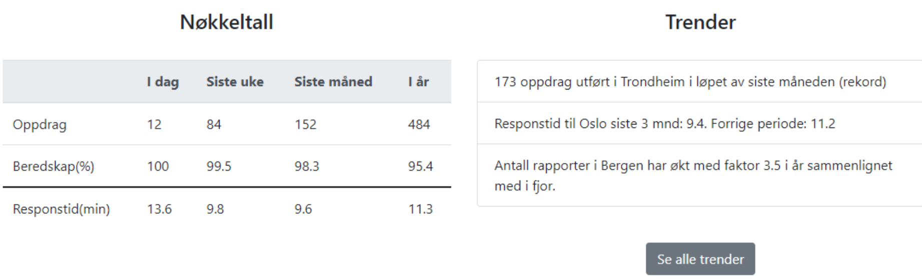

Figure 4.5: Prototype II - a dashboard showing key statistics on the left and recent trends on the right.

Figure 4.6: Prototype II - the trend page showing various trends with links to the layout visualizing them.

not implemented, and all graph visualizations had data sets consisting of the last 1 and 3 months.

Login system

The purpose of the login system is to control who has access to NOLAS Insights. All users with access to prototype II had the possibility to register themselves in order to log in to the system. The login page is shown in figure 4.7. All pages except the login and register pages require the user to be verified. When a user logs in, the information is sent to MongoDB, which responds whether the JSON Web Token (JWT) is valid. If the JWT token does not exist or is expired, the user is not able to access protected content.

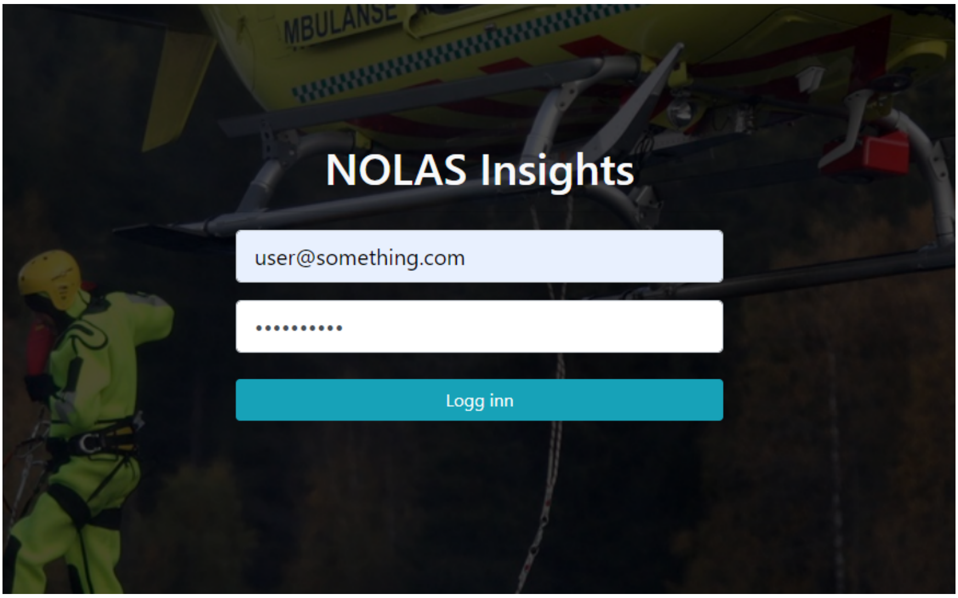

Figure 4.7: Prototype II - the login page.

4.4 Prototype III

The main focus of prototype III was to improve the design, implement the period filter and incorporate real data. The use of boilerplate code in the previous prototype led to the choice of making the system from scratch, to get full control of the system. The evaluations of the previous prototypes inspired a new design, and the Semantic UI library was used to style the components. At the start of this prototype phase, NAA's data was ready to be extracted from the NOLAS database system. Therefore, logic to extract, process, and visualize the data was needed. See appendix B.3 for more screenshots of the prototype.

4.4.1 Design

The main design goals of prototype III was to improve the navigation menu, the dashboard, and the operational performance layout. Prototype III utilizes the component-styling framework Semantic UI, which simplifies the process of styling user interface elements.

Operational performance layout

Figure 4.8 shows the new design of the operational performance layout, which includes changes to the graph, base filter, and period filter. The empty space under the graph is

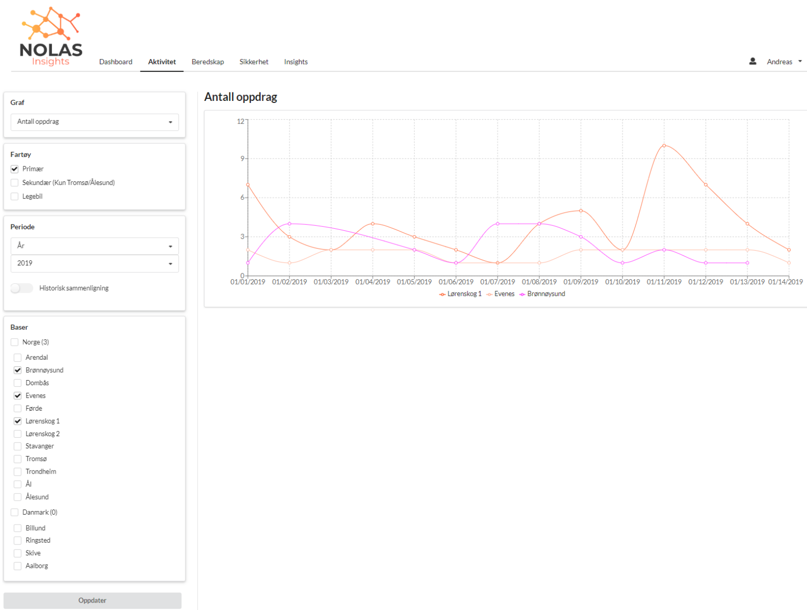

Figure 4.8: Prototype III - the operational performance layout.

missing the table included in previous prototypes, as other features were prioritized in this iteration.

The graph shown in figure 4.9 is created with the library Recharts[5], which offers thorough documentation and a lot of functionality. The primary reason for changing the graph library to Recharts was that it was easier to work with. In prototype III the only selectable graph types were *number of missions* and *response time*, which led to the initial choice of displaying the data in line graphs.

Figure 4.9 reveals weaknesses of the graph implementation. No data point is drawn in the graph when there is a lack of data, for example, when no missions are logged throughout a day. This leads to broken lines in the visualization, and the right side of the figure exemplifies this with the Evenes data set. Additionally, the date label format on the x-axis is month/day/year format, instead of using the Norwegian convention of day/month/year. The graph quickly became cluttered with data points regardless of the period duration as it showed data points for each date. Only the start of the period was therefore visualized.

The revised filter design is seen in figure 4.10. A checkbox for Denmark and Norway was implemented, to simplify the process of selecting a group of bases. The vehicle filter is added to differentiate between the types of vehicles performing a mission, but is only added on pages where the filter is applicable. The introduction of page-specific filters makes the choice of stacking the filters vertically natural.

[5]Recharts: https://github.com/recharts/recharts

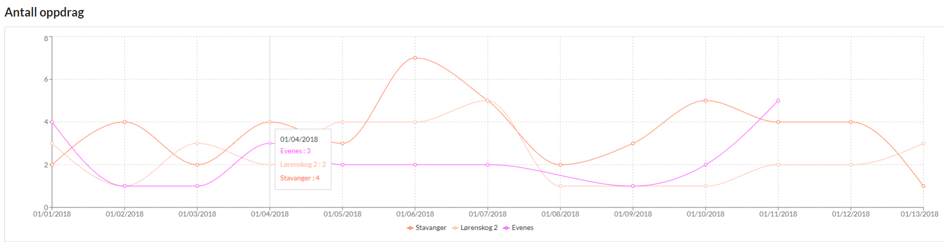

Figure 4.9: Prototype III - a graph showing the number of missions executed in three bases. A tooltip is displayed when the user hovers over a data point.

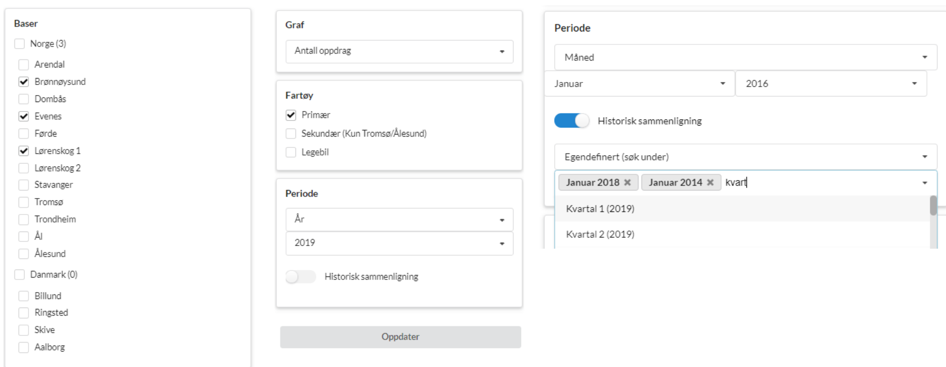

Figure 4.10: Prototype III - the filters. Left: the base filter. Middle: filters for the graph type, vehicle and period and the update button. Right: the period filter with historic comparison enabled.

The period filter lets the user select a main period (*Month*, *Quarter*, *Year*, or *All time*) by setting the values of up to three dropdowns. To see process fluctuations, the user can toggle historical comparisons to reveal a layout with two dropdowns. In the first dropdown, the comparison type is set to be either custom or the 1—9 prior periods to the main period. The custom options allow the user to compare different period types, for instance, July 2018 with the second quarter of 2017. The lower dropdown displays the selection of historic periods and allows periods to be added through text search. A selected period is removed by clicking on the x icon next to the period label.

Dashboard

The new draft of the dashboard introduces graphical visualization of the multiple categories shown in figure 4.11. The layout was based on the dashboard template offered in CoreUI[6], reducing the effort of the implementation. The approach to the dashboard design revolves around creating a content-filled dashboard testing multiple ideas in order to determine their value. The dashboard shows key number and availability statistics in colored

[6]CoreUI: https://coreui.io/react/

graphs, patient characteristics, system usage statistics, and social media following.

Navigation menu

The new navigation menu is shown in figure 4.12. When the user views the *Dashboard* page, a line is drawn beneath the corresponding menu item. The line suggests what the current content is and that the user can change it. The menu includes a logo for NOLAS Insights and the name of the user is displayed on the right. The *Miscellaneous* category was removed after discussions with NAA, and two categories were renamed (*Mission* to *Activity* and *Trends* to *Insights*).

4.4.2 Functionality

The logic that prototype III requires to become functional revolves around the use of the operational data stored in NOLAS. As the operational data is sensitive, it must be kept secure, which eliminates the option of having a direct link to NOLAS. Instead it is better to acquire the data through representation state transfer (REST) requests. The remaining problems consists of sending appropriate requests based on the filter component properties and processing the extracted data in order to visualize it. The complexity of these tasks was reduced in this prototype by only creating them for the graph types *Number of Missions* and *Response Time*.

Extracting NOLAS data while keeping it secure

To make the extraction of NOLAS data as secure as possible, only the necessary NOLAS data is made available in a Filemaker layout. A Filemaker layout is a limited view of the data stored in NOLAS, and the content can be extracted securely by sending a REST request with an authentication token. The parameters of the request decide the response, and this way only the necessary data can be requested. The Filemaker layouts give NAA control of the kind of data that NOLAS Insights can access, and the access can be revoked in the event of a data breach. Bo Conneryd and André Thoresen from NAA helped the authors with setting up and maintaining layouts throughout the project.

To lower the layout complexity and make data retrieval efficient, the layouts were grouped into separated layouts for *Mission* (available in this iteration), *Availability* and *Security*. The *MissionLayout* contains data related to each mission with fields like date, response time, and mission type. The *AvailabilityLayout* hosts daily statistics about issues with technical equipment or crew regulations[7] that affect a base's ability to respond to emergency events. The *SecurityLayout* represents information about reports that are filed in relation to incidents.

[7] Crew regulations: The crew can only work a limited set of hours without resting by law.

Figure 4.11: Prototype III - the dashboard showing statistics of key numbers, contingency, patient-characteristics, users of the system, and social media.

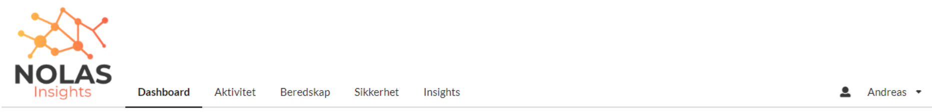

Figure 4.12: Prototype III - the navigation menu provides navigation to the following pages: dashboard, mission, contingency, security, insights, and user.

Mapping filter state to requests

The filter state that needs to be converted into requests is the graph type, the main period, and the base selection. The historical comparison option allows multiple periods of different types to be selected, but only the main period is utilized for sending requests in this iteration. The *MissionLayout* did not contain data linking missions to vehicle type, resulting in a non-functional vehicle filter.

The prototype III request approach is simple and involves sending a request that retrieves all necessary data. To provide interactive visualization, the original idea was to continuously update the graph as the filters were changed. Due to the overhead of the large single request, the *Update* button shown in figure 4.10 was introduced.

Response parsing

The response parsing logic requires grouping operations on the response as it contains all mission data for all bases. The list of missions received in the response is processed by executing the following operations:

1. Group the missions by date
2. Group the missions on each date by base
3. Aggregate data based on the graph type
    (a) Response time: find the average response time that day
    (b) Total missions: find the number of missions
4. Add aggregated data specifying base and date to the list with graph data

After the data of the response is processed, the graph data is sent to the graph component which visualizes the data sets.

4.5 Prototype IV

The focus of prototype IV was to refine the basic version of the system by improving the usability and usefulness of the system. Feedback from the previous user tests led to several changes to the graph filters, the graph component, and the dashboard. The graph

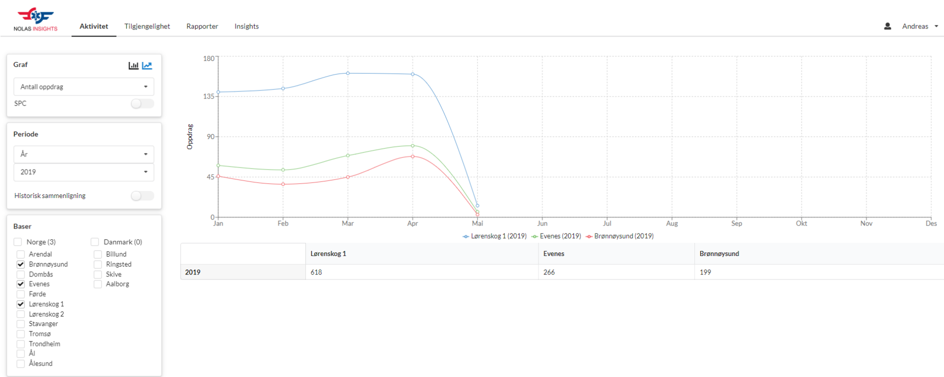

Figure 4.13: Prototype IV - the operational performance layout showing the number of missions executed in 3 bases in 2019.

type support was increased from 2 to 6, as the *AvailabilityLayout* was finalized by NAA. The request logic was optimized to make the system more efficient and stable.

4.5.1 Design

The overarching goal of the design in prototype IV was to make the system simpler and more self-explanatory, based on the problem areas revealed through user evaluation. The *Dashboard* page (renamed to *Insights*) was made less cluttered with an increased focus on medical data. Several changes were made to the graph component to make it easier to interpret, including a table providing a numerical view. The changes to the graph filters include removing the update button, simplifying the selection of historical periods, and making the base filter require less vertical space.

Operational performance layout

The revised operational performance layout can be seen in figure 4.13.

The graph quickly became cluttered with data points because a point was drawn for each date in the data set, regardless of the period type. To make the graph more readable, data points were grouped together to represent a period in time instead. If the period type is *month*, the data is grouped by day. The grouping is done by month for the period types *quarter* and *year*. The new period type *from* spans over a range of years and the data is aggregated for each year.

The graph component received multiple visual improvements, some of which can be seen in figure 4.14. The graph component supports the display of data with bars instead of lines and the ability to switch between these styles. A new color scheme with more distinguished colors was added to make it easier to differentiate multiple data sets. A y-axis label was added based on the graph type displayed. The scaling of the y-axis was made

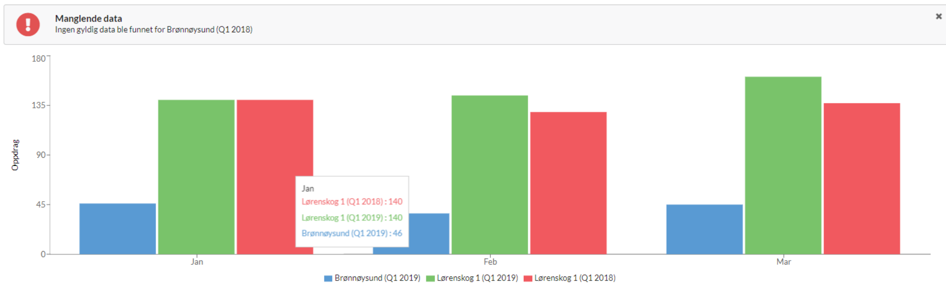

Figure 4.14: Prototype IV - the graph component comparing the number of missions in two bases in 2019 and 2017.

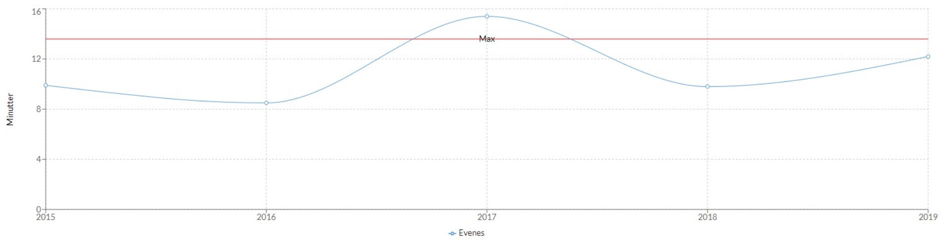

Figure 4.15: Prototype IV - a response time graph with the new period type *from* and a line indicating the value one standard deviation above the average.

more sensitive to processes where the differences are small to make it possible to distinguish similar values. The graph also supports historical comparisons, and the data set labels include a description of the time-frame they represent. Whenever the user changes a setting requiring an update of the graph, the progress of the data retrieval job is indicated to the user with a loading bar. A dismissible message above the graph is displayed when there is missing data for a base in a period, shown in figure 4.14. A lack of data is common due to recently established bases.

Initial support for process control is introduced in the graph component. Figure 4.15 shows a line drawn on the y-axis indicating the value that is one standard deviation above the average of the data set.

Figure 4.16 shows the table implementation summarizing data for each base in the periods. Similar to how each data point in the graph is an aggregation of data in a period, the table aggregates the values of each data set. While the graph shows the development of the process within the period visually, the table represents the development numerically.

In the period filter the historical comparison is made functional and less complicated. In prototype III the historical comparison could be set to be either custom with any type of periods or the 1—9 prior periods to the main period. This made comparisons of quarter 2 in 2018 and July 2018 possible, but it was established that such comparisons have low value. This led to the decision to remove custom period comparisons and make the selection as

	Brønnøysund	Lørenskog 1	Billund
Kvartal (Q1 2019)	128	445	285
Kvartal (Q1 2018)	0	406	360
Kvartal (Q1 2016)	0	407	278
Kvartal (Q1 2014)	0	376	0
Kvartal (Q1 2011)	0	405	0

Figure 4.16: Prototype IV - the table component summarizing the number of missions in quarter 1 for multiple years and bases.

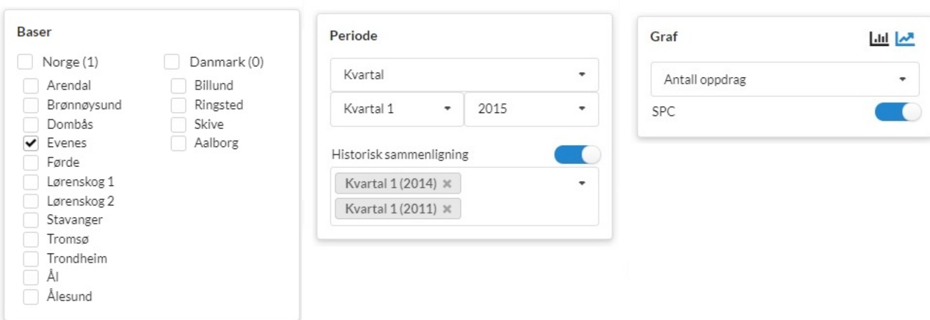

Figure 4.17: Prototype IV - changed filters. Left: the base filter. Middle: the period filter. Right: the graph filter

shown in figure 4.17. All prior periods to the main period are displayed to the user when clicking inside the historical comparison field.

The period type *all* was changed to *from* in order to make the period more customizable. Retrieving all historic data for multiple bases requires a lot of requests, so setting the default period to the last 5 years is therefore beneficial. The *from* period type is a multi-level dropdown where the starting year is selected, making the selection process more consistent with the other period types.

Other changes were made to the vehicle, graph, and base filters in addition to the *Update* button's removal. The vehicle filter was removed as NAA could not provide the necessary data within the time frame of the project. Figure 4.17 shows the Norwegian and Danish bases being aligned side by side, allowing the filter to require less vertical space. Toggle switches for process control and graph style was added to the graph filter. By clicking the bar or line icons shown in figure 4.17, the selected style is indicated with a blue color, similar to the look of historical comparison being enabled. The optimization of the request logic allowed removal of the *Update* button, meaning no user action is required to update the graph after changing the filters.

Insights - the new dashboard

The layout of the *Insights* page can be seen in figure 4.18. The view of the key numbers and trends are reverted to the design in prototype II but are stacked vertically to the left to make

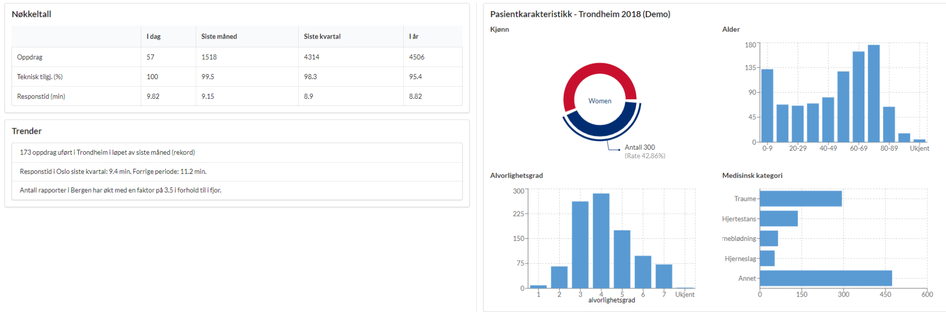

Figure 4.18: Prototype IV - the *Insights* page showing operational key numbers, trends and patient characteristics.

space for the medical layout on the right side. The availability graph, the user statistics, and the social media following components are removed due to the lack of interest in them. The removal of these elements made the whole layout fit within the screen, removing the requirement of having to scroll.

The medical layout shows the age, gender, and medical characteristics of the patients that NAA are treating. These characteristics are not present in NOLAS but are stored in different medical systems depending on the base. Integration with all of these systems is unrealistic. Storing the data in NOLAS requires approval and is something NAA wishes to do in the future if they are granted permission. The goal of the layout was to show the potential of storing patient characteristics in NOLAS. Data from 2018 in Trondheim was supplied to make the numbers as realistic as possible. The goal of the layout is to facilitate discussions about how the users want to utilize the medical data.

4.5.2 Functionality

Prototype IV improves the performance by sending multiple requests only if it is necessary, in addition to setting up structure that makes it easier to implement new graph types as NAA supplies data for them. The new graph types of prototype IV are *Total Availability*, *Technical Availability*, *Flight Time*, and *Flight Time per Mission*.

Sending multiple requests

The new request approach involves sending a request for each data set. A data set represents base-specific data during a period. This means each line in the graph corresponds to a data set. The approach is efficient in terms of retrieving a minimal amount of data and allows smaller individual operations on the data sets. If the user selects a new base, one request is sent as opposed to the prototype III approach where all data are requested and processed again. The reduction in processing time spent to handle filter changes made continuous updates and removal of the *Update* button possible.

Keeping request data in state

The time spent waiting for responses represents most of the loading time in the application, and the new request approach makes it easier to keep track of the requests have been sent. When a response is received, it is saved in a list with the period and base as a key. A callback function is called whenever the filters are changed and sends requests if they are not already present in the list of responses. The list of responses is kept in state as long as the user stays on the same page.

Supporting new graph types

As more data for graph types becomes available, it is important that the structure of the system makes adding them to the system easy. The *Mission* and *Availability* layouts do not share the structure, which makes it natural to have layout-specific methods that process the data. The missions or availability events is first assigned to a period. The data point that represents the period is calculated by a method specific to the graph type that determines the value based on the data in the period. Implementing graph types where numerical values are averaged or summed is straight forward. Other graph types, like *Total Availability*, require more effort. To calculate the *Total Availability*, the duration of the period is compared to the unavailability in the period. The last step to adding a new graph type is to make it available in the graph type dropdown on the appropriate page.

4.6 Final prototype

The goal of the final prototype of NOLAS Insights was to make the system ready for production and to add important functionality that remained. An invitation system was implemented, and the system was made accessible online in order to uncover bugs that reduces the stability of the system. The structure in the navigation menu received final changes and measures were taken to increase the system usability. The logic was improved in the component *CategoryLayout*, which controls the operational performance layout. Support for three more graph types was added. The medical layout was moved from the dashboard and replaced with a layout that shows monthly operational trends on a base level. The server runs a monthly occurring job that processes historical data to determine recent trends in each base. This section ends with a summary of how the different components in the final prototype work together.

4.6.1 Design

The last design iteration brought changes to the operational performance layout and replaced the medical demo on the *Insights* page with a layout showing the most recent trends. The *User* page was updated and gives an overview of the users and the number of graphs

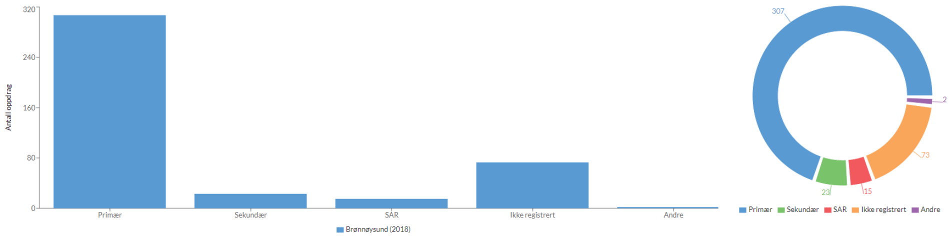

Figure 4.19: Final prototype - the mission type distribution in a Norwegian base in 2018. The bar style is shown to the left, while the pie style is on the right.

they have created. Administrators can send users invitations by email, and delete users in the interface.

Operational performance layout

In the operational performance layout, the graph gets support for distribution graphs, and figure 4.19 shows a distribution visualization with both the bar and pie style. The new distribution graph types are *Mission Type*, *Flight Time per Mission Type*, and *Medical Category of the Patient*. For distribution graph types, multiple selected bases are treated as a group, and all of the base values are summarized.

The tooltip that appears when the user hovers over data points sorts the labels in a descending order by value, instead of the order they were inserted. Figure 4.20 shows what the tooltip looks like, where the top and bottom of the list identifies the bases with the highest and lowest values.

The support for process control is increased by showing lines for one, two and three standard deviations off the data set average. Figure 4.21 shows that the line color goes from yellow to red when the standard deviation offset is higher.

Two summarizing columns are also added to the table. The columns calculate the total in each period and for each base, like the table implementation in prototype I.

The demo of the medical layout was moved from the old *Dashboard* page to a new *Medicine* page with a period and base filter. The filters are disabled to indicate that they are non-functional, while they express the usefulness of seeing patient characteristics for a specific set of bases in a certain period.

Figure 4.21 shows the new approach to displaying graphs in periods that are ongoing. The main period is 2019 but the graph only show data for completed months. Showing data for incomplete periods gives a faulty impression of the operational development, and incomplete periods are therefore not visualized anymore.

Figure 4.22 shows the introduction of the mission type exclusion filter and the final base filter. The excluded mission types are selected in the same way as historical periods, by clicking on elements in a searchable list. Only the mission types that are not selected will

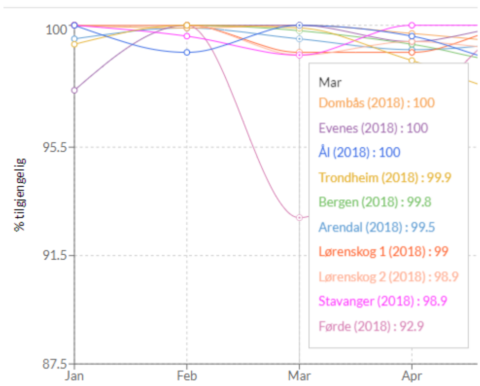

Figure 4.20: Final prototype - the tooltip labels are sorted by descending value.

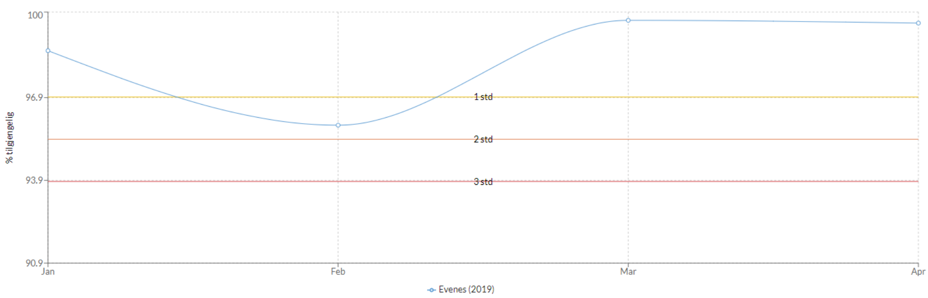

Figure 4.21: Final prototype - the process control setting enables three lines that indicate up to three standard deviations of the average.

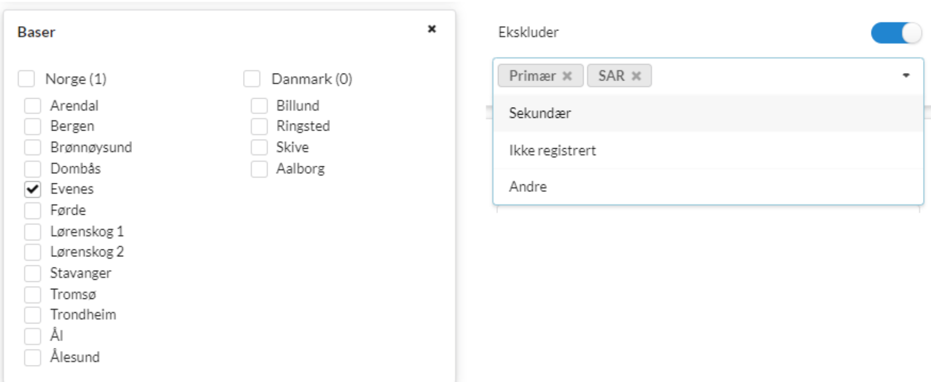

Figure 4.22: Final prototype - the final base filters on the left and the new filter that excludes mission types on the right.

be included in the data that the graph and table utilize. The base filter gets a clear selection icon in the upper right corner, which is visible whenever a base is selected. Clicking the icon removes the selection of all bases.

Insights

The *Insights* page separates the air emergency operations of Norway and Denmark and presents the key numbers and recent trends for each of the countries. Figure 4.23 shows the grid implementation that indicates the country of operation with the country's name and flag at the top. The *Insights* page was moved to the left in the navigation menu to represent the home page, and can also be accessed by clicking the NOLAS Insights logo in the top-left corner.

The trend layout shows base-specific trends per month and is shown in detail in figure 4.24. The left and arrow buttons in the black header let the user change which month they are viewing trends for. Trends are determined for *Response Time*, *Technical Availability*, and *Total Availability*, which all relate to the contingency of NAA's operation. When the user hovers over a trend icon, a tooltip is displayed with text explaining what the trend is, as well as a button with the text "Go to graph". Clicking this button redirects the user to the corresponding graph in the operational performance layout with appropriate filter settings. The color of the trend indicates if it is positive, and says something about the number of months the trend has been occurring for. Table 4.1 describes the color of each trend type, where the darkest colors indicate a severe development over one month and the lightest colors represent gradual developments over three months. The coloring of negative trends corresponds to the colors of the process control lines. When a process throughout a month qualifies for multiple trends over different time-spans, corresponding icons are stacked side by side.

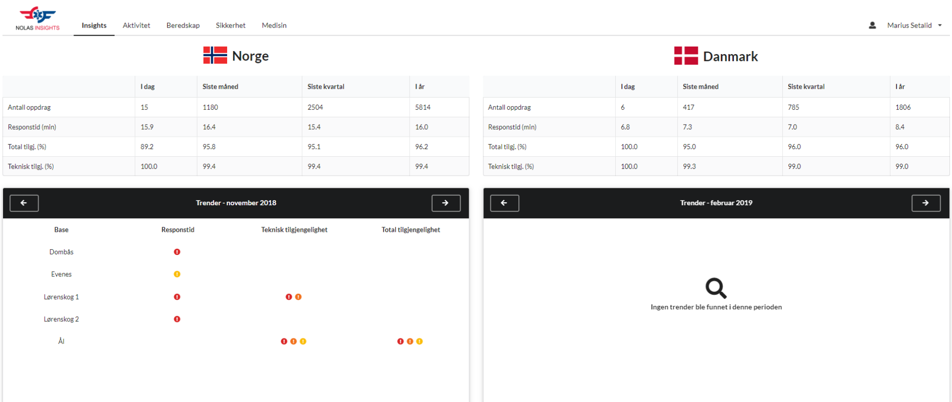

Figure 4.23: Final prototype - the dashboard showing key statistics and trends for NAA's operation in Norway and Denmark.

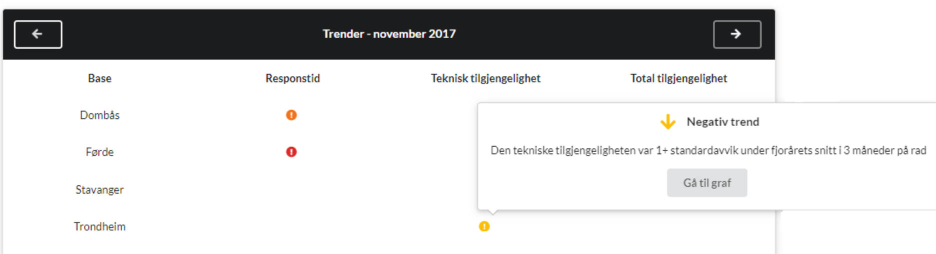

Figure 4.24: Final prototype - the tooltip shown when a trend is hovered explains the trend and offers a link to a graphical explanation.

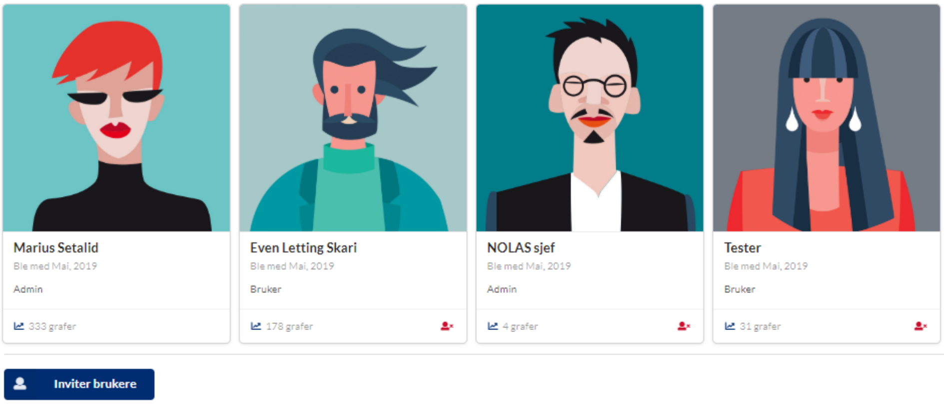

Figure 4.25: Final prototype - the *user* page shows details about the users of the system.

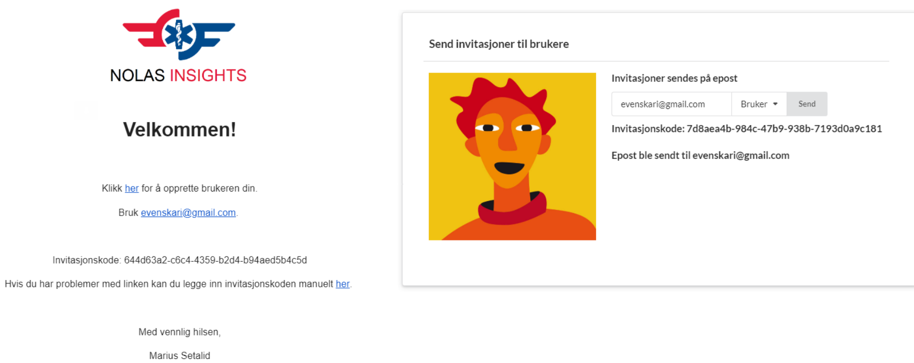

Figure 4.26: Final prototype - the mailed invitation new users received on the left, and the interface administrators used to invite them on the right.

User administration

The *User* page got a new layout that gave an overview of the users of the system, shown in figure 4.25. The overview shows details for each user including their *Name*, *Date Joined*, *Account Type*, and *Number of Graphs Created*. A user profile picture is randomly generated for each user. Administrators are able to delete existing users and can invite new users to the system. The interface administrators use to send out invitations is shown in figure 4.26 and gives the option to invite the user as an administrator or a regular user. The figure also shows the email that the invited users receive, which contains a link that takes them to the registration page with the invitation code automatically filled in.

4.6.2 Functionality

Common component for operational performance

A goal of the final prototype was to generalize the component responsible for showing the operational performance. In the previous prototype, there was a component for both the *Activity* and *Contingency* page, and the need to unify them became apparent. The logic that sent new requests based on filter changes was duplicated in the components, and a request from NAA during the iteration showed a lack of flexibility in the components. NAA wanted to move the graph type *Response Time* on the *Activity* page to the *Contingency* page. This was not possible because the *Contingency* component could only extract data from the *Contingency* layout. The component *CategoryLayout* is introduced to solve these problems and unifies the logic for the *Activity*, *Contingency*, and *Medical* page.

In the component *CategoryLayout*, data for each of the different layouts are requested and stored separately. This made it possible to show graph types linked to different layouts on the same page and added support for the combination of data. The support for combination of data is important with regards to the future development of the *Security* page, as it requires data from both the *Mission* and *Security* layout.

Determining trends

Monthly operational trends are determined for each base at the start of each month for *Response Time*, *Technical Availability*, and *Total Availability*, which relate to the contingency of NAA's operation. Table 4.1 shows the list of trend types and their characteristics. A trend is a positive or negative process development throughout a period of one to three months, based on the standard deviation of the process in the previous year. A trend of one month means the value is three or more standard deviations of the last year's average. A two months long trend requires an offset of two or more standard deviations throughout the period, while a three month trend requires one or more. The trend criteria are based on the approach of the International Civil Aviation Organization (ICAO) in finding abnormal trends (Teo Gim Thong, 2015). NAA is currently working on incorporating ICAO approaches and is expanding the safety performance indicators they are monitoring. It is therefore beneficial to support the approach of ICAO in determining trends to make the system stay relevant in the future.

At the start of each month, a task is scheduled in the backend server to find the trends in the last month. The task runs at midnight and is scheduled by the scheduler provided in the npm package called node-schedule[8]. The task also involves updating trends of the two previously completed months, in case the operational data is changed or updated. For recently established bases, trends are not to be determined until there are three months of valid data in the preceding year. Each base is also linked to a creation date that makes it possible to discard invalid availability data. The availability was previously assumed to be

[8]node-schedule: https://www.npmjs.com/package/node-schedule

Trend type	Duration	Minimum standard deviation offset	Color
Negative	1 month	3	Red
Negative	2 months	2	Orange
Negative	3 months	1	Yellow
Positive	1 month	3	Dark green
Positive	2 months	2	Green
Positive	3 months	1	Light green

Table 4.1: The properties that classifies certain operational development to constitute a trend.

100% unless there were events of unavailability, but the introduction of the base creation lets the system also verify that the base existed at the time.

Invitation system

The invitation system ensures that the system access is restricted to invited users, as a measure to protect the sensitive operational data. Each invitation contains an invitation code, the role of the invited user, and values to indicate if the invitation has been used or has expired. The invitation code is a universally unique identifier and is generated with npm package *uuid*[9]. When an invited user registers an account, the email of the user must also match the email the invitation was sent to. The backend part of the application handles user registration requests and checks if the registration is valid or not. Only administrators are able to invite and delete users.

4.6.3 System overview

NOLAS Insights is a web application that utilizes a client-server architecture and extracts data from the NOLAS database system. The purpose of the system is to extract and convert operational data into useful information and present it to the management of NAA in an intuitive way. Figure 4.27 shows a structural overview of the final system, where the components *Insights* and *CategoryLayout* are important. Both of these components extract data from NOLAS, and use standardized methods from the utility file *ResponseLogic* to process it. The NOLAS data is extracted by making REST requests to NOLAS layouts, which represent a subset of the data in NOLAS.

The *Insights* component is the landing page of the website, and shows the key numbers and trends of NAA's operation. The component separates statistics for Norway and Denmark. The *KeyNumbers* component shows the contingency characteristics and number of missions in each country during the last day, month, quarter, and year. Displayed beneath, the *Trends* component shows contingency trends. A month selector lets the user look at historic trends, and by hovering a trend the user is presented with an explanation of what

[9] https://www.npmjs.com/package/uuid

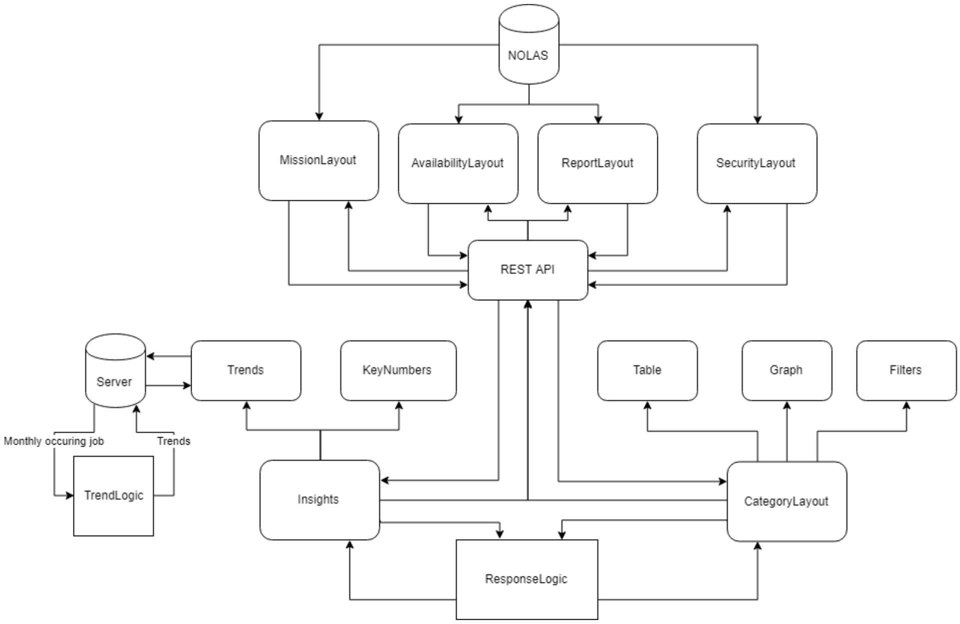

Figure 4.27: Final prototype - structural overview of components and data flow

the trend implies. The user can navigate to the trend by clicking a button presented in the hover dialog.

CategoryLayout is a component that visualizes the operational performance with the use of a graph, table, and filters. It is responsible for sending REST requests when the user makes changes to the filters and for updating the graph and table when the responses are processed. The *Graph* and *Table* components present operational characteristics. The graph is shown with a bar, pie, or line style depending on the graph type and filter settings. The table aggregates the data points in the graph and summarizes the process numerically in a table showing values for bases and periods. The graph filter lets the user change the graph type and toggle certain graph settings. The period filter decides the time frame in the graph and whether comparison with periods from other years should be included. The base filter decides the selection of bases.

Chapter 5

Results

This chapter presents the results from the evaluation of the NOLAS Insights prototypes. The physical setup used to evaluate the prototypes is described in section 3.2.1. Each of the five prototypes are evaluated in a user test, usually followed by a semi-structured interview. The main design considerations found in each evaluation are presented. Statements from the user evaluation are translated and presented in English, with the purpose of capturing the essence of the Norwegian statements.

5.1 Evaluation of prototype I

> Subject 1: ”The system is intuitive and easy to navigate”.

The aim of prototype I is to get early feedback on a low-fidelity prototype that gives a broad outline of the system. This ensures that resources spent on system development is used on functionality that the users desire. Five subjects participated in the evaluation of the prototype.

5.1.1 User test I

User test I guides the user through the entire system and the user must navigate, use filters, and interpret visualized data. The fourteen tasks the user test consists of are listed in B.1.2.

Navigation menu

The user test tasks involved entering different parts of the system, which required the user to navigate. No users had problems with tasks that required changing the page by clicking items in the navigation menu. The subjects seemed to be familiar with the use of a navigation menu and subject 1 stated; ”It is intuitive and easy to navigate. I am used to using these type of menus”.

Filter usage

The filters used to show data includes the graph filter, the period filter and the base filter. The functionality of the graph and period filter was simulated by the test leader. If a user clicked on one of these filters, the test leader would show the subject the dropdown that was supposed to appear. The use of these filters came natural to the subjects when tasked to find data of a certain type in a certain period for a set of bases. The subjects seemed to be familiar with the filter design as subject 4 stated that ”the filters seem really user friendly for people that are used to our NOLAS filtering system”. Some remarks were made about the text size in the filtering options being small.

Interpreting data

The tasks which involved finding base-specific information or comparing performance of bases led to discoveries. The subjects used both the graph and the table to identify data, but they made remarks about the visibility and meaning of the displayed data. The graph sketches did not contain any numbers or units of measure, making it impossible to determine numerical values with the graph. The subjects had to use the table to find numerical values, but the table also lacked units of measure. When visualizing the response time in task 6, it was not obvious to the subjects that the response time unit was in minutes.

The *Map* page showed a sketch of an interactive map which visualized the path of missions from and to the base. Subject 3 said: ”The characteristics of the mission is interesting, but not where you have been”, and other subjects indicated that the value of the map was low. Another concern with the *Map* page revolved around the use of exact GPS coordinates required to draw the mission paths, which could link a mission to a patient if combined with other data.

5.1.2 Interview session I

The goal of the first interview session was to discuss the potential and need for NOLAS Insights, and how the approach to the system met their expectations. The most important functionality was deemed to be visualization of operational statistics, base comparisons and finding trends. Generally, the participants felt the project was exciting, and that looking up information in the prototype was intuitive. The interview dives deeper into the users’ perception of the system.

What do you think about the prototype?

Subject 1: The subject is excited and thinks the project has great potential. Says it is extremely important. The key thing is to tune what the system is showing you in a way that makes it relevant and meaningful. The subject expresses interest in being able to freely change the period, but stresses that it is important to look at an average over three years, because of the big yearly fluctuations which is affected by things like weather. There might not be any information gained by comparing April this year with April last year, but rather comparing April this year with April the last five years.

Subject 2: The subject thinks the system is good, and has a consistent layout. The subject highlights that the navigation between categories is intuitive, which makes the system easy to learn. The subject wants less text on the landing page.

Subject 3: The subject feels that the system is intuitive and easy to navigate.

Subject 4: The subject says that Norwegian Air Ambulance (NAA) already has access to a lot of statistics in NOLAS, and that NOLAS is something everyone is already used to working on. The subject thinks having another system on the side could be problematic. The subject stresses that it has to provide something more than what exists in NOLAS.

Subject 5: The subject says that it is a user-friendly system, especially for people that are used to work with the filtering system in NOLAS. In the subject's position data from NOLAS is commonly used to make graphs, so the system is useful for him. The subject says that it will be a good tool for the management, but maybe not the crew.

Was anything unnecessarily difficult?

Subject 1: The subject thought that nothing was unnecessarily difficult. The subject repeats that the system is simple and intuitive and knows what to look for in the system.

Subject 2: The subject says that nothing was unnecessarily difficult.

Subject 3: The subject repeats that the system was intuitive and easy to navigate.

Subject 4: The subject says no.

Subject 5: The subject has some remarks about the text size in the filtering options being too small, especially concerning the base filter.

Was anything inconsistent or was there anything you would like to do in another way?

Subject 1: The subject thinks the system was consistent, and does not have any further input.

Subject 2: The subject expresses that the developers have done a good job. The subject says it is a simple and efficient system.

Subject 3: The subject thinks the system was intuitive, and does not have any further input.

Subject 4: The subject repeats the fact that it needs to be obvious that this system is different from the existing system NOLAS. This is something new, that they are not used to working in. The subject thinks this is problematic.

Subject 5: The subject starts by stating: ”No”, and starts to tell about problems with the existing system NOLAS. NOLAS contains so much information, that it is hard to retrieve the information you want. The subject hopes that NOLAS Insights can be used to optimize this retrieval of relevant and good information.

Did you think the system was easy to use?

All of the subjects repeated that they thought the system was simple to use.

How often do you have the need to use a tool like NOLAS Insights?

Subject 1: The subject says that the system will be used between weekly and monthly. If the system is easily available, the subject says it will be used more.

Subject 2: Monthly use is the first thought that struck the subject. The subject says the system might be used daily for certain things. The subject says that the ability to export things from NOLAS Insights to Excel or PowerPoint would be really useful.

Subject 3: The subject did not have a definite answer. The subject says that they usually create reports on a monthly basis, but that this is a tool that goes beyond reporting. The subject thinks it will be used more frequently when the team members get used to the system. When emerging issues arose, the team members would use it if they knew the system could assist.

Subject 4: The subject thinks that the system will be used daily, as long as the person is on duty.

Subject 5: If this system gives an overview of compliance, security, and mission statistics, the subject thinks the system will be used several times a week.

What functionality in NOLAS Insights do you think will be most useful?

Subject 1: The subject says that deviation is interesting, in relation to contingency especially. The subject wants to look at how many missions that have been rejected, and how many that have been interrupted. If they could get insight into why they could not fly a specific day, they might be able to do more flights in a year. The subject also states that pure statistics is useful, as it can be used to make arguments.

Subject 2: The subject thinks that the *Contingency* and *Mission* categories will be most useful.

Subject 3: The subject says that it could possibly change over time. The subject expresses interest in contingency processes, missions, compliance, security, and how well they are doing technically.

Subject 4: The subject focuses on the map in this question. The subject says that visualization of the mission type is interesting, but not the paths of the missions. The subject admits some usefulness to visualization of the paths, but is concerned with GPS coordinates ending up in the wrong hands.

Subject 5: The subject says the most important thing is statistics relevant to their customers (the government of Norway and Denmark). The subject wants insights into how their level of service fulfills the contract requirements. The subject lists categories like *Contingency*, *Compliance*, and *Missions*. The subject thinks the system definitely can be used to find out why the response time in Trondheim is generally worse than other bases, but focuses more on system error and not human error. Highlights the concern of adding more categories and graphs types when the project is concluded. The subject feels this is an important part of the system, not that the system itself is customizable, but that the functionality can be expanded easily.

How do you want to be able to compare data?

Subject 1: The subject says that development over time is interesting, but only if the relevant periods can be chosen. The subject thinks it is interesting to be able to look at the profile of a base, and see it compared to others. The subject exemplifies this by saying it would be really interesting to compare bases like Bergen and Trondheim, which have similar conditions.

Subject 2: The subject says that the system should be able to provide filters that separates primary and secondary missions, as well as vehicle type (regular ambulance or helicopter). The subject suggest that the *Miscellaneous* category is moved to the right in the navigation menu.

Subject 3: The subject wants to be able to compare sick leave and budget deviation. The subject says that sick leave statistics could help increase the availability of their service, by acquiring backup pilots when necessary. The subject wants to get insight into periods with low technical availability to identify problems. Such periods can lead to crowded repair shops or budget problems, which can affect their ability to meet the contract requirements they are bound by. The subject finishes by stating that despite being able to aid the economy of NAA, the purpose of the system is not to make money.

Subject 4: The management wants a lot of filtration possibilities, like seeing aggregated statistics for a selection of bases. The subject thinks it is really good if the system allows unnecessary information to be filtered away. The subject says; ”It is mostly interesting to look at the bigger picture”. The subject feels like the response time is a touchy subject, because competition between bases can endanger lives. The subject finds comparisons of response time with the contract requirements beneficial.

Subject 5: In the subject's position, comparing categories is not very interesting. The subject acknowledges the usefulness the system has for some people. The subject feels that comparing bases over a period of time is most important.

Other thoughts that arose during the interviews

NAA acknowledges that the structure of the data in NOLAS is suboptimal. For example, the type of search and rescue missions is registered, but not in a sortable way. Data like this is registered in free text. It would be very valuable for them to visualize the data to make it look like it had been registered well. It will help to motivate the crew and management to focus on logging good data. In addition to displaying real data, the system can display potential of the system with fake data.

5.1.3 Design considerations

The main design considerations established in the evaluation of prototype I is:

1. The navigational structure of the system seems logical to the users.
2. It is important to distinguish the operation of Norway and Denmark, as they have different contract requirements.
3. Comparing development in a base over time is more important than comparing it with another base.
4. NAA is improving their use of data, and NOLAS Insights should support this

5.2 Evaluation of prototype II

> Subject 1: ”The categorization of missions, contingency, and miscellaneous is in line with what I want”.

Prototype II was the first website prototype of NOLAS Insights, and allowed more realistic functionality testing with dummy data. The prototype was evaluated by four subjects.

5.2.1 User test II

User test II takes the user through the entire system to get input on navigating the system, the design in the operational performance layout, and the login system. The nine tasks of the user test are listed in B.2.2.

Design

The design of prototype II represents the web implementation of 5.1, and the users were able to use and navigate through the system in a similar manner. Prototype II was more interactive, and no issues were discovered regarding using elements like dropdowns and checkboxes to select the graph types. Important findings:

- One user felt that the look of the navigation menu should indicate the clickability and purpose of the menu better. The user expected the menu option selected to be visually indicated.
- Another user expressed confusion when trying to find a specific trend while looking at the summarized view of the trends in the *Dashboard* page.
- The users were easily able to locate the information in the *Dashboard* and Trend layout once they were on the correct page.
- When tasked to find the response time located in the contingency page, two of the users commented that they expected to find it under activity.

Operational performance layout

In the layout visualizing operational performance it was important to investigate how the users interacted with the filters and how the information in the graph and table was interpreted. The use of filters to set graph type, period, and base selection came natural to all users, but some usability problems were discovered.

The graph type and base filters were functional. Changing the graph type worked fine, but when the users had to select a specific base they had to do several operations to only select the base in question. The option to select or deselect all bases in a country in one click was suggested.

Some of the tasks involved determining values with the use of the graph and table. The users tended to solve the tasks by trying to interpret the graph first, for example when finding the amount of missions done for two bases. Two users used the tooltip that appears when the user hovers over a data set. After executing a few similar tasks, the users started to use the table more frequently to find the numerical values. However, the exact meaning of the numbers was not always obvious to the users, as they still lacked units. One subject suggested big numbers, like 16000, to be made easier to read by adding spaces, commas or dots.

5.2.2 Interview session II

The interview questions in prototype II is similar to the questions in the previous prototype. As this is the first functional prototype, it was important to test some of the basic aspects again.

What do you think about the prototype?

Subject 1: ”The system is easy to navigate”. The subject says that it is important to work on the relevance of the data and the layout of the pages. The categorization is in line with what the subject wants.

Subject 2: The subject thinks the navigation menu is hard to see. The subject says that buttons and lighter colors might make the navigation menu more obvious. Otherwise the subject thinks the system was easy to use.

Subject 3: ”I think this system is really good”. The subject gives input on some of the potential of NOLAS Insights. The subject says that NOLAS is a platform where some IT experts provides specialized solutions to extract necessary data when creating annual reports. The subject feels that NOLAS Insights has great potential to optimize the current approach, and there is potential for always using the system to generate reports. The subject would like some kind of export of the data in NOLAS Insights, and is mostly interested in export to Excel.

Subject 4: The subject says that the system was very easy to use, did not display too much info, and was easy to navigate.

Was something inconsistent or would you do something differently?

Subject 1: The subject comments that the NOLAS database might be more categorized than is directly known, and suggests that NOLAS Insights can use this to incorporate more graph types. The subject adds that a thorough investigation of the data in NOLAS is required.

Subject 2: The subject is interested in *Air Time* and *Average Air Time per Mission*. The subject wants these categories on the *Mission* page.

Subject 3: The subject comments about aborted and rejected missions. The subject says that aborted missions are relevant, but that rejected missions is not something that is being registered in NOLAS today. The subject explains that weather conditions can result in rejected missions.

Subject 4: The subject does not have any suggestions for doing things differently, and does not comment about inconsistencies.

What is this system lacking the most?

Subject 1: The subject does not have anything to related to add, and says ”the system looks very promising”.

Subject 2: The subject feels that there is need for more report statistics, and adds; ”the system is easy to use”.

Subject 3: ”I think it is fine as it is”.

Subject 4: The subject will not use it in its current state as the system does not display any relevant information at this time. The subject needs data about the crew, like sick leave and overtime, in order for the system to be useful.

How do you want to compare base data? With regards to data categories, bases and time frame.

Subject 1: The subject wants support for seeing data in the last 30 days or last 365 days. The subject also wants to see the last calendar month and calender year. The subject says it is mostly interesting to compare a period with data from the year before. The subject says such comparisons should be possible for periods like month, quarter, and year.

Subject 2: The subject usually compares one year to another. The subject says it is mostly interesting to see a month or year compared with the previous year.

Subject 3: The subject stresses the need to compare on a yearly or monthly basis with the period in the year before. The subject says; ”I do not know if it is interesting to look at the data three years ago, since the organization has had extreme growth the last few years”.

Subject 4: The subject is not interested in the statistics that NOLAS Insights provides, and feels that makes it hard to give input on data comparison. The subject is interested in overtime, sick leave, and other crew-related statistics.

Other thoughts that arose during the interviews

The general consensus of the management was that a map visualizing operational aspects was cool, but the usefulness of it was not obvious. Some of the subjects said it was not necessary to have it in the system at all, that it should not prioritized in early stages of the development.

5.2.3 Design considerations

The main design considerations established in the evaluation of prototype II was:

1. The navigation menu and trend tables needs to be more visible.
2. Base selection needs to be more efficient.
3. The data needs to be easier to understand.
4. The most interesting periods are month, quarter and year. Comparisons with previous periods should be possible.

5.3 Evaluation of prototype III

Prototype III introduces a new design and extracts data from NOLAS instead of using dummy data. Four subjects participated in the prototype III evaluation.

5.3.1 User test III

User test III investigates how the subjects approach the new way of presenting information in the operational performance layout and the dashboard. The 10 user test tasks are listed in B.3.2.

Operational performance layout

The subjects were able to understand most of the information displayed in the graph, but one of the subjects commented that the colors of the data sets was too similar. When looking at the graph for the amount of missions, subject 1 commented; ”When I look at the missions in 2017, I want to see an accumulation of missions. Bars instead of a line would have been more useful”.

One of the tasks involved finding the amount of missions that occurred on a specific date. The subjects struggled to interpret the dates on the x-axis, as expected due to the unconventional month/day/year format. After finding the data point two of the subjects found the amount of missions by hovering over the data point to display the tooltip. Subject 2 suggested the bases in the tooltip to be alphabetically sorted. The two other subjects used the y-axis to find the value. When viewing the response time of bases subject 3 had problems to determine the value accurately as the data points had big differences. Subject 3 said: ”I think secondary missions are included here”, and secondary missions were not applicable to the response time requirements of NAA.

In general, the subjects were able to successfully use the filters. The subjects used a few extra steps to configure the period filter correctly initially. However, as the subjects accomplished more tasks involving different period options, they made less mistakes. This implied that the period filter had a learning curve, but was fairly easy to get familiar with. Subject 3 found the base filter to be a bit inefficient and suggested; ”Here I would like a button that cleared the whole selection”. The filter layout was not able to fit within the screen height of the Mac used in the test, which required the subjects to scroll down to click the update button. No subjects had issues with locating the button.

Dashboard

The reactions to the new dashboard design were constructive and mostly negative. Subject 3 said: ”The dashboard looks messy. It looks very fancy, but it gives me nothing”. The findings in the dashboard can be summarized to:

- A label at the top of the dashboard saying February 2019, indicated that the dashboard summarized the last finished month. Subject 1 thought it would be more valuable to show the development over multiple, longer periods.
- Four colored graphs under the period label showed the amount of missions, response time, insights (trends) and total reports in the period. Two of the four subjects struggled to find the amount of reports in the graph to the right. Subject 4 identified the four graphs, looked at them briefly without finding the report graph, before starting to scroll down the dashboard.
- When asked to determine the availability of NAA in the period the subjects struggled to make sense of the contingency graph. Subject 4 said: ”This graph does not make much sense, as knowing the daily availability has low value. To combine numbers for Norway and Denmark does not make sense either, as they have a different set of rules”. The numerical values on the continuous line was hard to eye ball and the time frame of the graph was not obvious.
- The subjects were interested in the patient layout, but they thought the visualization could be better. For example, by visualizing the diagnosis type in a pie chart or by illustrating the patient characteristics with varying icon sizes based on the distribution.
- The layout with user statistics did not get much attention, and was considered to be a non-critical part of the system.

5.3.2 Design considerations

The main design considerations established in the evaluation of prototype III was:

1. The graphs should support different visualization styles like lines and bars.
2. Data points needs to be aggregated into groups to ensure a more readable graph.
3. The dashboard components must be made more intuitive and the amount of them should be reduced.

5.4 Evaluation of prototype IV

> Subject 3: ”The medical statistics on the insights page excites me, but it deserves its own space”.

Prototype IV refines a basic version of the system and changes to the dashboard and operational performance layout needs to be tested. Four users took part in the evaluation.

5.4.1 User test IV

User test IV tests the design changes to filters, the graph component, and the new *Insights* page that replaced the *Dashboard* page. The seventeen tasks that the subjects performed are listed in B.4.2.

Navigation

Registering and logging in using an invitation code was trivial for all of the subjects. This implies that an invitation system will be a good way to increase security in the upcoming prototype. To access user information, the users had to open the user option menu in the navigation menu and select the settings tab. This seemed unnatural for the subjects, as only two of the subjects tried it. The subjects encountered less problems in next tasks related to the user page design, which included finding out how many graphs the subject has created in the system, and to invite a new candidate through the invitation system.

Operational performance layout

In the task where the subject had to identify the base with the lowest response time in Norway, two of the subjects commented that the colors in the graph were too similar.

Changing the graph style, between lines and the newly implemented bars, seemed intuitive and easy to find for all of the subjects.

The message with information about missing data seemed to be noticeable for most of the subjects.

The selection of main period was not always obvious to the subjects. For example, when asked to compare May in 2016 and 2015 it was hard for some subject to understand that they needed to filter by month, and not year. This seems to be a learning problem, as it was more present in the subjects that were new to the system.

The subject experienced problems with the historic comparison filter, as it only showed periods prior to the main period. Throughout the user test, most of the subjects tried to add periods that were after the main period multiple times. Subject 3 had the most difficulties with historical comparison, but said that ”you just have to get used to it” and did not see a huge issue with the constraints of the filter.

It was generally hard for the subjects to find values in the tooltip in the graph. When trying to identify the lowest technical availability in the graph it was difficult due to the data not being sorted, as well as the colors being so similar as explained before.

Another issue that came to light in the user tests concerned the display of incomplete periods. According to subject 1, NAA does not want to show incomplete periods to avoid misleading visualizations. The number of missions in a year of four completed months is not comparable with last year. This concerns all of the period type configuration in the system.

Insights - the new dashboard

The subjects were asked to locate key number, trends and medical data on the *Insights* page. The previous tasks involved locating data in the operational performance layout, and the subjects seemed to be influenced by this. Two of the subjects always navigated back to the graph layout when prompted to find information located on the *Insights* page.

The input on the trends varied, and the users found them hard to locate and used long to determine the most important trend. One of the subjects asked why is this important to know, and what you are supposed to do with it. This implies that the representation of trends made them hard to understand, and should be visualized in a different way.

The subjects felt it was unnatural to have medical data in the insights category, and requested moving it to a separate page. When the subjects finally found the medical data on the *Insights* page, none of them had problems with interpreting the medical data.

5.4.2 Design considerations

The main design consideration established in the evaluation of prototype IV was:

1. Make the user page more easily accessible.
2. Showing data for incomplete periods is misleading.
3. Give medical data its own space, supporting base and period filtering.
4. Clarify the meaning of trends.

5.5 Evaluation of the final prototype

The final prototype incorporates final changes to the operational performance layout, introduces base-level trends in the dashboard, and adds an interface for user administration. Four subjects participated in the evaluation.

5.5.1 User test V

User test V investigates the usability of the operational performance layout and how the subjects interprets data in the dashboard. The 13 tasks of the test are listed in B.5.2.

Operational performance layout

The period comparison filter in prototype IV only showed periods prior to the main period, but was updated to show all of the possible options. No subjects had problem with the tasks that involved use of the comparison filter. However, subject 3 suggested that a comparison period should be chosen by default when the period comparison is enabled.

A filter that excluded mission types from the visualization was also tested, and ended up revealing a problem with the response time values. The subjects managed to exclude secondary missions with the use of the filter, and this exclusion was expected to yield more realistic graph values. When viewing the response time graph subject 3 said: ”The response time is still around 26 minutes. Ambulance missions in cars is probably included here. That makes the graph pretty meaningless”. The data to distinguish air ambulance missions from regular ambulance missions was available in NOLAS, but was not available in the layout that NOLAS Insights extracted data from.

The subjects were successful in locating and using the updated process control filter to determine months of operation where the response time deviated. Subject 1 wondered what the lines exactly indicated, but identified the deviating months. Subject 3 mentioned how the lines were colored similarly to the trend icons.

Dashboard

The first task in the dashboard was to identify useful information in the table with key numbers. The subjects found the response time and availability statistics to be the most important of the key numbers, except subject 4 who did not find them useful at all.

When asked to find trends in February, all of the subjects managed to use the arrow buttons to display the trends for February. 3 of the subjects instinctively hovered over the colored trend icon to display the trend tooltip. One of them clicked the button that links to the graph showing the trend to explain it, while the others read the tooltip. Subject 1 read the tooltip to explain the trend, but indicated unfamiliarity with the term standard deviation.

User page

The last task involved finding out the role of their system user. One of the subjects needed help to locate the user overview, but all of the subjects were able to identify their user role when viewing the overview.

5.5.2 Interview session V

The questions in the final interview session seeks to gather overall impressions of the system, in terms of *learnability*, *ease of use*, *satisfaction* and *efficiency*.

How is this system to learn in relation to other systems?

Subject 1: The subject thinks it is fairly okay to learn. The subject says; ”Today we have only tested a small part of the system, and I managed to navigate it. It is pretty self-explanatory”. The subject initially needs to look around to find certain things, but finds it easy to remember things like where a certain graph type is located.

Subject 2: The subject thinks the system is very easy for people that work with statistics.

Subject 3: ”It is very intuitive”.

Subject 4: The subject says that the practical experience is needed to get familiar with the functionality and to learn how to navigate the system.

How is the system to use?

Subject 1: The subject repeats that the system is mostly self-explanatory. The subject adds: ”it is beneficial that the system does not require a big amount of training, as opposed to NOLAS”.

Subject 2: ”It is very simple, memorable. Intuitive. You can fumble a bit with a button or the choice of a menu, but after having done it once it is quick to do the next time”.

Subject 3: ”The first impression is that it is logical. I have the advantage of being involved in the development process, but I think it is intuitive for people not involved as well”.

Subject 4: The subject says it is manageable, but requires some experience. The subject thinks the system was quick to get used to.

Will this system be useful for you? If no, what is missing?

Subject 1: ”Yes, absolutely”.

Subject 2: ”To the highest degree, I think the system is actually very important to us”. The subject adds that value of the system comes from providing an operational overview and that it can highlight the importance of data quality. The subject hopes the system can work as motivator for increasing the quality of the logged mission data.

Subject 3: ”Yes, I think so”.

Subject 4: The subject says: ”No”, as it does not contain useful statistics for the subject’s management position.

To what degree does the system visualize operational characteristics and trends?

Subject 1: ”I feel the system does this really well, especially if the data is adjusted slightly to what we need. The way the data is visualized is really good”. The subject exemplifies the usefulness of trends linking to the graphical explanation.

Subject 2: ”It seems correct, in terms of having good graphs. You also get more detailed information from the graphs, but some of the data needs to be verified. At this point we cannot treat the graphs as the full truth, but they work as a good starting point”.

Subject 3: ”Operational characteristics are shown in a good way by the use of graphs and alternative graphs with the parameters we desire. The use of colors in the trends works as a red flag”.

Subject 4: The subject comments that a graph alone does not give much value, and is worth more if it is related to NAA’s goals.

Chapter 6

Discussion

This chapter starts by revisiting the desired system properties of NOLAS Insights. Based on the five prototype evaluations, we discuss the usability of the system and present validity concerns regarding how the data was obtained. Lastly, the chapter presents the findings of the study related to the research question.

6.1 Revisiting the desired system properties

The desired system properties from the preliminary study are shown in 6.1. The system was found to satisfy all of the properties with high and very high priority.

P1: The system extracts operational data from NOLAS with the use of a representational state transfer (REST) access point interface (API). REST requests are made to NOLAS layouts, which contains a small subset of the data in NOLAS.

P2: The system protects NOLAS data by restricting access to invited users of the system.

#	Property	Priority
P1	Extract operational data from NOLAS	Very high
P2	Secure extracted data from NOLAS	Very high
P3	Determine operational trends	High
P4	Visualize operational characteristics for bases	High
P5	Compare operational characteristics in a period to prior periods	High
P6	Compare operational characteristics in one base to another	Medium
P7	Export of graphs and data	Medium
P8	Customizable experience for each user	Low

Table 6.1: The desired system properties of NOLAS Insights established in the preliminary study.

No operational data is stored on the server, and in case of a web site breach only data made available in the layouts is at risk.

P3: Determining operational trends is partially supported in the system. Each month the system processes historical data for response time, availability and total availability and determines positive and negative base trends. Prediction of trends is not supported.

P4: Operational characteristics are visualized in a graph and a table component. Nine out of the 19 graph types that Norwegian Air Ambulance (NAA) requested at the start of the project was implemented. One graph type was not implemented due to the time constraints of the project, the *SecurityLayout* with data for five graph types was not completed, and the data to support the four remaining graph types did not yet exist in NOLAS.

P5: Operational characteristics in a period can be compared with prior periods of the same duration. The comparable periods are limited to month, quarter and year.

P6: The system supports visualization of data sets for multiple bases simultaneously.

P7: Export of graphs and data is not supported.

P8: The system does not support a customizable user experience.

6.2 Validity

The validity of the methods is important to establish the credibility of the results, and this section presents how the validity concerns presented in 2.4.2 may have influenced the results.

The internal validity decides the confidence of the results. The number of people in the management team of NAA is low (12-14 people), and some subjects participated in multiple prototype evaluations. Repeated testing of a system makes the users familiar with the system, but the familiarity is somewhat mitigated by differences in the prototypes. The user test tasks shared similarities throughout the prototyping, but we tried to focus on new functionality in each prototype. The complexity of the tasks was reduced for repeated testers, especially in tasks related to navigation and filtering. The questions in the interviews were designed to be as objective as possible in order to not influence the answers. The sessions were audio-recorded to reduce selective recall bias. Reviews of the sessions improved the accuracy of the results by identifying smaller details that could go unnoticed. Additional data could have been attained by video-recording the sessions. A video could be used to identify additional usability problems by looking at body language and approaches to the user tasks. The equipment and environment of the sessions resembled the conditions that the system will be used in, and strengthened the ecological validity. The conditions that match are the use of a browser to access the system on a computer and being located inside the office premises. However, the users were being observed in a test situation instead of using the system to do their ordinary job.

The external validity of the results may be lower, as it is hard to generalize results from evaluating a product made for a specific group of people. The management team of NAA is a highly specialized group, and does not represent the rest of the population. The user test tasks were designed to represent real use cases for NAA, and not for an organization in general. This increases internal validity, but decreases external validity.

The project was limited by the number of available subjects during the evaluation, and averaged 4.2 subjects per test. According to (Nielsen, 1994a) around 79 % of the usability problems should be identified using such a small sample. The nngroup[1] recommends testing around 5 subjects, but 4 to 5 people per user test should be enough to identify the biggest usability problems in the system. Using a lower number of subjects made multiple evaluation iteration possible, and reduced the use of resources and cost of the project.

6.3 Usability

The usability of NOLAS Insights was a focus in the evaluation of the final prototype, which attempted to assess the learnability, efficiency, memorability, and satisfaction of the system. The subjects found the system to be relatively easy to learn, especially for the users that were familiar with statistics. New users required some hands-on experience with the system to become familiar with the functionality. Efficiency is hard to measure qualitatively, and needs to be evaluated at a later time. The subjects found the system to be simple and intuitive to use. It required some time getting used to, but after having done something once the subjects found it easy the next time. This reflects the memorability of the system. It was found that NOLAS Insights requires less training than NOLAS, which is an important finding as this may make the system more preferable over the existing system. The satisfaction was measured by asking how useful the system will be for NAA, and to what degree the system visualizes operational characteristics and trends. In the last interview almost all of the subjects said that the system will be very useful to them. However, the system still lacks statistical reports that are important to some members of the NAA management. It was found that NOLAS Insights visualizes operational characteristics well, but some of the data needs to be validated better. The trends are in line with what NAA requested, especially the red flags that notifies the user of significant operational development. Overall the usability of the system indicates that NOLAS Insights is able to achieve many goals of the management of NAA.

[1] https://www.nngroup.com

6.4 Research question

Which design considerations must be made to give the user an overview of the operational situation?

The design considerations found in the evaluation of the five prototypes relates to how the system is structured, understanding characteristics of the operational situation, and how the users interpret information in the system.

The structure of a system decides how its functionality is indicated, accessed, and how hard it is to modify in the future. The results from evaluating NOLAS Insights show that the grouping of operational characteristics into pages accessible in a navigation menu was logical to the users. Another important consideration is that NAA is modernizing their use of data with the desire of incorporating new graph types in the future. This was addressed in the last two prototypes by making data extraction more flexible, and generalizing the component responsible for visualizing graph types.

To give the best overview of the operational situation, it was important to establish what was most important to the management team of NAA. In the evaluation of prototype I and prototype II it was found that the users generally had a ”divided interest” in statistics offered by the application, and some subjects missed some statistical output related to their own management area. The users shared an interest in seeing how the base characteristics deviate, especially in terms of comparing the development over multiple periods. As an operator following different regulations in Norway and Denmark, high-level overviews of the operation needs to be separated by country.

The results of the user tests made it possible to improve how the system conveys the operational situation to the users. The system presents a summary of the situation on the landing page and operational characteristics in the operational performance layout. The approaches to the design of the landing page showed that too much information quickly became excessive for the users and that the summary needs to be concise. The iterative evolution of the operational performance layout was guided by the approach of the users to find and interpret operational characteristics. The evaluation process with user tests revealed usability problems and provoked the users to reflect and brainstorm better design solutions in the interviews. The results indicated that NOLAS Insights will be used more frequently if the users know that the system can assist in solving a problem. This indicates that the perceived usefulness is important for system adaption, a finding supported by the study of Davis on user acceptance (Davis, 1993).

Chapter 7

Conclusion

This chapter concludes the thesis and presents future work that can improve the usefulness of NOLAS Insights in the near future.

7.1 Conclusion

This research project investigated how a business intelligence system can provide an operational overview of the air ambulance operations of NAA. A lot of data is logged for each emergency mission, but the input data needs to be systemized and should be made easily accessible to authorized team members. The system provides the management team of NAA with information that lets them see operational developments that can assist in decision-making. The innovation of the system comes from its ability to automate and modernize the way NAA gets their operational overview, and in the long run may contribute to improved performance and possibly budget savings. As a specific research effort, NOLAS Insights is considered to be a satisfactory contribution of this thesis.

Throughout the iterative development and evaluation of NOLAS Insights important design considerations have been established to guide the development. Joint efforts and good collaboration between the researchers and the NAA management team was important in this project. The design considerations are closely related to the needs of the management team, and can therefore not be applied directly to other types of organizations that seeks an operational overview. The approach defined in the research method can be used to create similar systems, but the properties of the user group of the system must be taken into account.

7.2 Future work

The work that remains before the system can be considered complete consists of implementing safety performance indicators (SPIs), and validating data. The next step, incorporating medical data, is a challenge that should be possible to overcome in the near future which will be of significant importance for NAA delivering air ambulance services on a national level in two countries. The authors of the present thesis have been asked by NAA to continue development of the application, with a focus on SPIs and data validation, and both are motivated and interested to participate in this upcoming work process.

7.2.1 Safety performance indicators

NAA has recently started to use SPIs to control their operation and wants to incorporate SPI functionality in the system. The SPIs are either lagging or leading. Lagging SPIs indicate the historic performance of NAA, while the development of leading SPIs can help predict future performance. The authorities require NAA to define target values for each of the SPIs based on what is safe.

NAA have defined two lagging SPIs:

- Incidents defined as **serious** or **accidents**.
- Incidents defined as **moderate**.

NAA have defined seven leading SPIs:

- Loss of GPS capability.
- Moving map faults or lacks above a certain level.
- Fatigue that affects safety.
- Traffic conflicts.
- Air space violations.
- Technical incidents that affects safety.
- Weather related incidents that affects safety.

NAA wants to monitor the SPIs and get notified of severe developments. Developments can be identified by applying the existing trend logic to the SPIs, but the implementation must also take the target values of each SPI into account. NAA wants a solution where system administrators can set the target values for SPIs manually. The CEO of NAA says: ”It is a way for us as responsible leaders to pinpoint important areas of focus to avoid incidents, and to see if unwanted trends exists”.

7.2.2 Data validation

The data quality of the visualizations in NOLAS Insights is critical to NAA. A data validation test has to be performed by comparing the data in NOLAS with the extracted data in NOLAS Insights. This concern came up after NAA discovered discrepancies between annual reports and corresponding data in NOLAS Insights. NOLAS Insights extracts data from missions with regular ambulances and helicopters, but no data to distinguish the vehicle type was available throughout the development phase of the project. However, the necessary data was made available later. By introducing a vehicle filter, the hope is to resolve the data discrepancies. The solution might be more complicated, and if the vehicle proves unsuccessful, other factors must be investigated. The CEO of NAA says: ”We need to be able to trust the data, that is one of the most crucial aspects of the system. If we cannot trust the data, the entire thing falls apart”.

7.2.3 Incorporating medical data

One of the visions of NAA concerning NOLAS Insights was to incorporate medical characteristics of their operation. Storing medical data requires permissions that can take a long time to get approval for and was therefore deemed out of scope for this thesis. At the end of the project a medical supervisor said: ”The possibility for adding medical data looks good. It is no longer constrained as long as the data is not too person specific”. The initial characteristics NAA wants was demonstrated in NOLAS Insights; gender, age, degree of severity, and primary diagnosis of the patient.

The incorporation of medical characteristics change the process of the emergency crews and require a safe way of storing the data. The pilot is responsible for logging input data following each mission. In order to get the medical data the pilot must interact and collaborate with the doctor. The emergency crews might meet this new requirement with skepticism, but also enthusiasm. NOLAS is an old system that NAA does not have full control of. In the future NAA wants to move to a new system, but before this migration, they do not feel safe storing the medical data in NOLAS. A solution could be to store the medical data on an external system that communicates with NOLAS and NOLAS Insights.

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Appendix A

Preliminary study

A.1 The first project proposal

Systemizing, merging and visualizing data from multiple air emergency operations

Norsk Luftambulanse AS has multiple helicopter bases throughout Norway and Denmark. For each mission a lot of data is generated. This information consists of mission-specific data like response time of the crew and who is partaking as well as patient-related data throughout the journey from pickup to delivery. This data can be structured, visualized and made sense of in a better way.

We need to design an automated system that visualizes recent and historic data from the air emergency operations according to the customer's needs. Initially, the focus can be to compare the different helicopter bases. Before implementing this, a thorough validation of the data used would be beneficial, considering a lot the data is inputted manually.

Some helicopter base comparisons could be
• Response time (time spent to leave the base after the mission is received)
• Time to location in different types of weather
• Missions per day

There needs to be a notification system, ideally also based upon predictive analysis, to let people know if a base shows abnormal trends in certain categories. Every base has to follow a certain set of requirements in regards to for example response time, and would benefit from knowing if they are close to breaking any of these. Potentially, we could look at the different variables in conjunction with one another to see if they're correlated in order to make better predictions.

We could also expand this by including medical data from the missions to further give meaning to the data. This would be by the request of the customer, and would increase the need for good security as the data is sensitive. We might have to implement a system where we have to take access rights into account to limit what each person has the ability to see.

Figure A.1: The first project proposal

A.2 Conceptual design

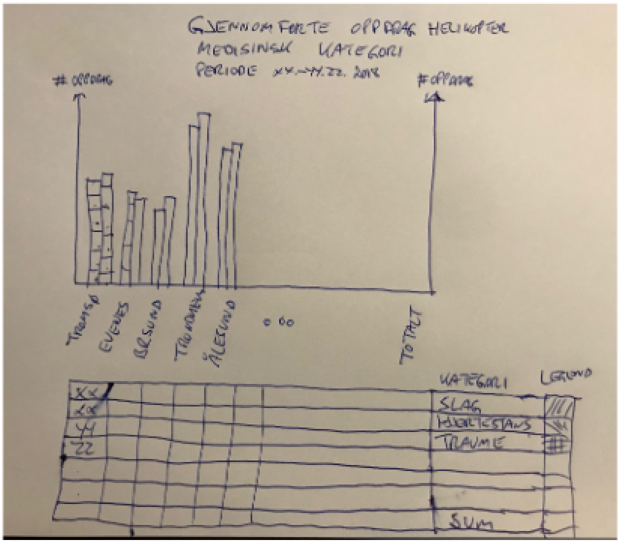


Figure A.2: NAA's conceptual design of operational activity. A graph shows the number of missions grouped by base, while the lower table underneath offers a numerical presentation.

A.3 Needs analysis of NOLAS Insights

Behovsanalyse av NOLAS insight

Hensikten med dette dokumentet er å gjennomføre en systematisk gjennomgang av behovet i forbindelse med utviklingen av NOLAS insight samt vurdere om behovet for dette er tilstrekkelig for videre gjennomføring.

Behovet

Norsk Luftambulanse AS (NLA) er eneoperatør for helikopterbasert luftambulansevirksomhet i Norge. Aktiviteten kan karakteriseres som komplekse luftoperasjoner hvis formål er å tilby spesialisert akuttmedisinsk helsehjelp til den alvorlig syke og skadde pasient i Norge. Liv står på spill, og krav til kvalitet på utført arbeid essensielt. Tjenesten skal levere svært høy regularitet hele året, og risikoprofil for luftambulanseoperasjoner ansees som høy.

Som operatør er det kritisk å ha oversikt over hvordan både enkeltbasene gjør det i forhold til resultatmål og hvordan organisasjonen gjør det som helhet målt mot en rekke resultatmål. Per dags dato har ikke NLA et automatisert verktøy som gir en slik oversikt, og styringsinformasjon på dette nivå genereres stort sett manuelt en gang i året. Målet med denne behovsanalysen er å gi ledergruppen i NLA et best mulig beslutningsgrunnlag for valg som må tas i arbeidet med å utvikle et bedre tilrettelagt informasjonssystem for monitorering av operativ drift .

NOLAS insight

NOLAS er NLAs IT driftsystem. NOLAS er designet av NLA selv og ligger på en Filemaker Pro plattform. NOLAS insight sikter på å løse behovet beskrevet ovenfor, og vil være et automatisert visualiseringsverktøy av ulike driftsprosesser relatert til NLAs virksomhet. Applikasjonen vil ta form som et dashboard, og lesemulighet via web er ønskelig.

Store mengder data fra ulike prosesser registreres daglig i NOLAS, men data i seg selv har liten verdi. Med NOLAS insight ønsker man å tilgjengeliggjøre denne informasjonen og tolke den på en slik måte at den gir mer verdi. Dette kan gjøres ved grafisk visualisering av dataene innenfor ulike områder, spesifikt for dette prosjektet: oppdragsaktivitet, beredskap og sikkerhet. Her vil sammenligning av resultatmål for basene innenfor ulike tidsrom være en viktig funksjon.

Ved å hente data i sanntid fra NOLAS, vil denne løsningen gjøre det mulig for ledelsen å monitorere virksomheten på en ny måte. I stedet for å generere resultatmålene på årlig basis, kan systemet tilby sanntidsmonitorering til enhver tid. Dette gir muligheten for varsling dersom ulike aspekter ved driften er utenfor definerte standarder, og ledelsen vil da raskt kunne iverksette tiltak. Da NOLAS insight kontinuerlig mates med data, vil systemet også kunne gi en oversikt over tjenestens beredskapssituasjon til enhver tid.

Figure A.3: Needs analysis of NOLAS Insights: page 1

Generelt vil verdien av slike monitoreringsløsninger avhenge av kvaliteten på datainput i kildedatabasen. Et sentralt element gjennom prosjektet vil derfor være å danne seg et inntrykk over om kildedataene er gode nok.

Forskningsspørsmål

Da utviklingen av NOLAS insight er i forbindelse med masteroppgave, vil forskningsdelen selvfølgelig være en sentral del. Det er mye vi kan ta stilling til her, men en prioritering må tas. For å få en tilfredsstillende innsikt må vi avgrense oss til ett, kanskje to temaer vi kan gå i dybden på.

Systemets effektivitet

- Which methods of visualizing operational data are the most effective in giving the user an overview of the operational situation?
- How suitable is the statistical process control methodology in detecting anomalies and deviations in NLA's operational processes?
- What machine learning techniques can be used to predict operational anomalies and deviations, and how accurate are they?

En kritisk del av NOLAS insight er brukervennligheten til systemet, og den vil til stor grad bestemmes av hvilke metoder som blir brukt for visualisering av prosesser. Vi ønsker her å benytte ulik analysemetodikk for å finne best egnet metode. Dette kan gjøres ved generering av empirisk data gjennom brukertesting og intervjuer. Videre kunne det vært interessant å analysere evnen systemet har til å detektere eller predikere avvik i resultatmål og regelverksbrudd.

Kombinering av data

- Could meaningful insights be gained by combining operational data (NOLAS) with medical data(other sources)?

Neste steg i prosjektet vil være å forsøke å kombinere data fra NOLAS med medisinske data fra helseforetakets database. Da det både er operasjonell og medisinsk data, så kunne vi undersøkt sammenhenger mellom disse og se om de kan gi mer verdi på denne måten. Da medisinsk data per dags dato ikke tilgjengelig gjennom NOLAS krever dette integrasjon med andre datakilder. I første omgang ville bruk av medisinsk data fra en eller to baser være aktuelt. Videre kunne man tatt stilling til hvorvidt en revisjon av NOLAS med enkelte medisinsk data ville vært hensiktsmessig.

Figure A.4: Needs analysis of NOLAS Insights: page 2

Datakvalitet

- To what extent can the data supplied from NOLAS be deemed of high quality? What kind of methods can be used for quality assurance?

Da datakvaliteten er kritisk for systemets nytte, kunne forskning innenfor dette også vært aktuelt. Dette vil omfatte en kategorisering av kvalitet innenfor ulike områder av dataen som er tilgjengelig. NLA er allerede i gang med en kvalitetssikring av NOLAS i regi av PositionEtt for å øke robustheten til systemet, med et fokus på å ha opplæring og oppfølging av all personell som registrerer data i systemet. Derfor er det litt usikkert hvorvidt vår analyse av dataene krever kvalitetssikring.

Konklusjon

NOLAS insight løser behovet til NLA for virksomhetsrapportering i stor grad og prosjektet har tilsynelatende lite risiko. Potensiale for å skape mye verdi og gjøre det lettere for å ta beslutninger for ledelsen er stor, og prosjektideen virker lovende.

Figure A.5: Needs analysis of NOLAS Insights: page 3

A.4 Graph types

Graph type	Description
Number of missions	The number of executed missions
Cancelled missions	The number of ongoing missions that are cancelled
Cause of cancelled mission	The reason an ongoing mission is cancelled
Cause of rejected mission	The reason a proposed mission is not accepted
Mission type	Examples: primary, secondary (transport related) and search and rescue (SAR)
Rescue mission type	Techniques used under special circumstances like avalanches, drowning and hard to reach locations
Flight operative category	The use of routines and flight assistance systems during missions
Flight time	The time spent airborne during a mission
Flight time per mission	Average time airborne per mission
Flight time per mission type	Average time airborne per mission type
Medical category	The diagnosis of the patient based on 6 main types
Response time	Time from a mission is accepted to airborne
Total availability	The % of time the service is available, which requires the crew and functional equipment.
Technical availability	The % of time the technical equipment allows the crew to go on missions
Number of risk events	Unexpected events which impacts safety
Number of high risk events	Unexpected events with increased safety impact
Risk events per hour of flight	The number of events per airborne hour
Risk event type	The event location. If it arose in flight, equipment, computer systems or on the ground
Risk events logged late	Risk events that are logged after the deadline period of time

Table A.1: The graph types NAA desired at the start of the project.

Appendix B

Prototypes

B.1 Prototype I

B.1.1 Screenshots

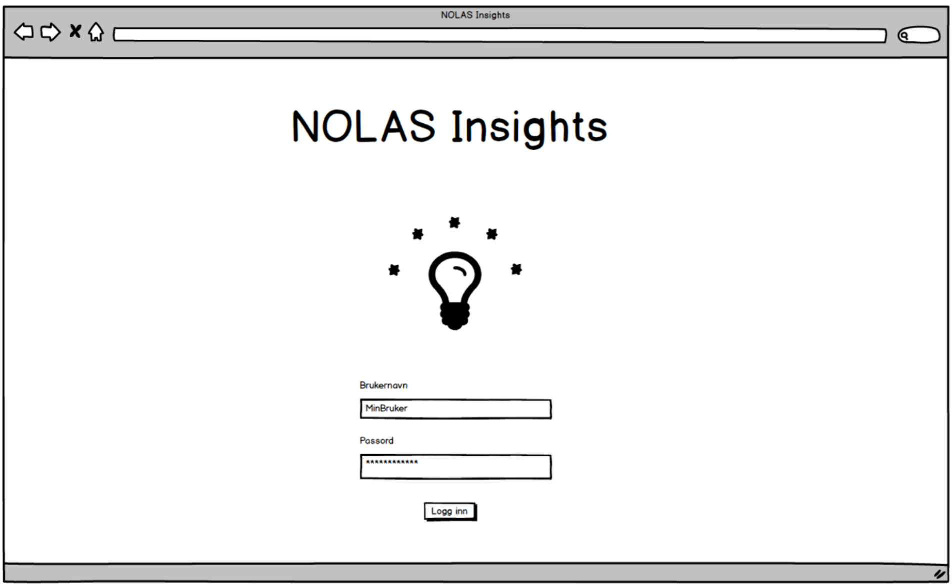


Figure B.1: Prototype I - the login page

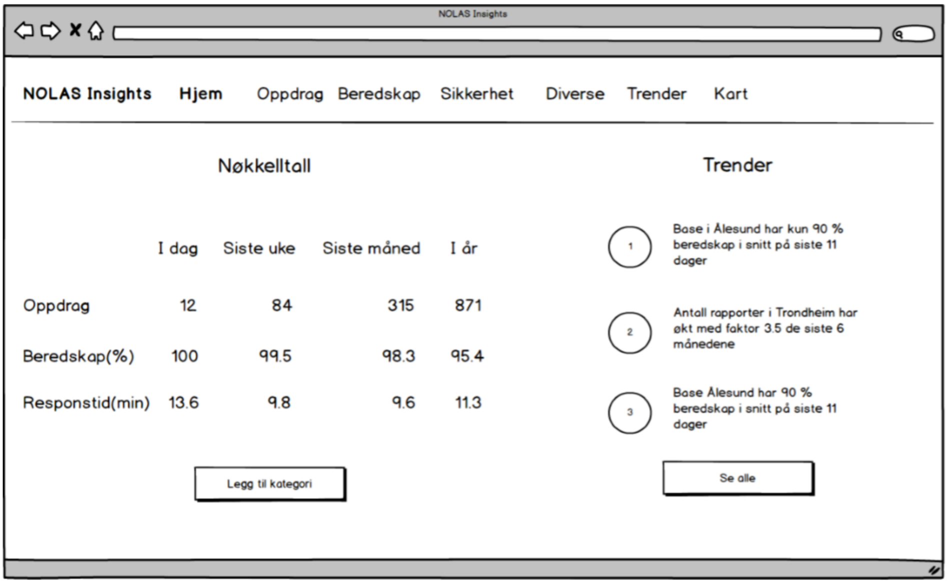


Figure B.2: Prototype I - the home page.

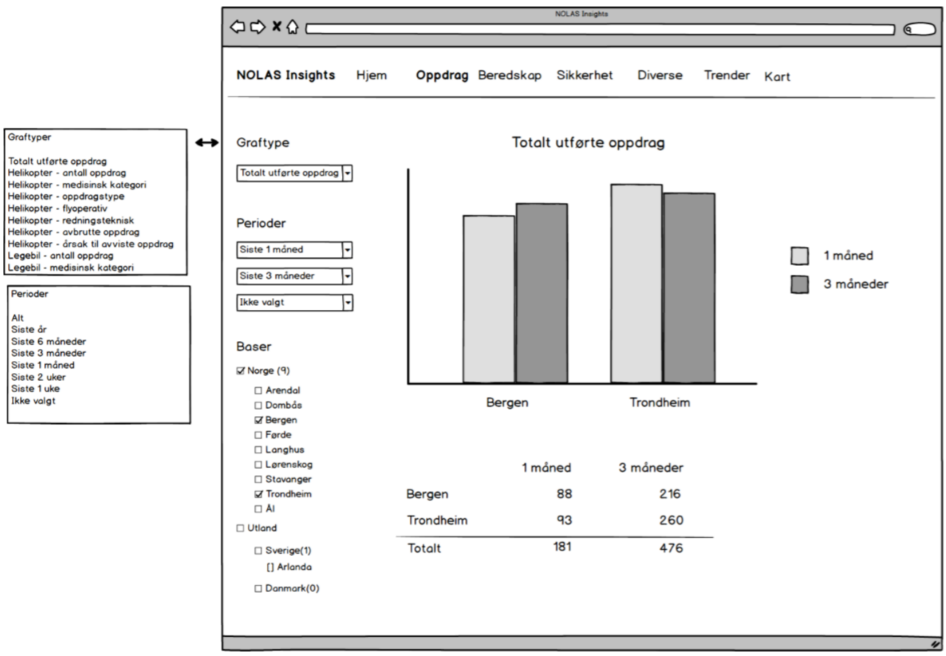


Figure B.3: Prototype I - the missions page.

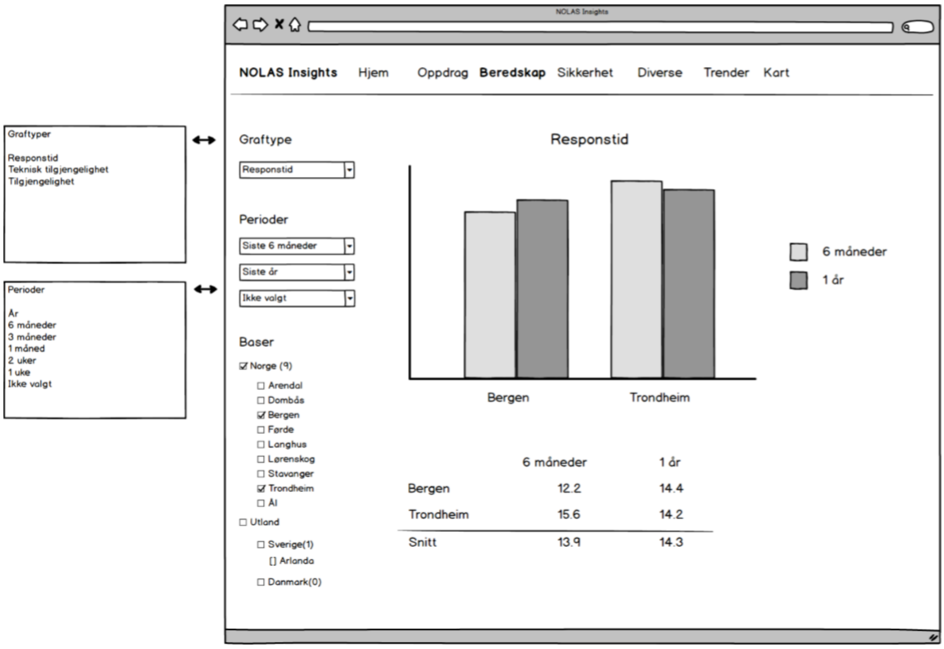


Figure B.4: Prototype I - the contingency page.

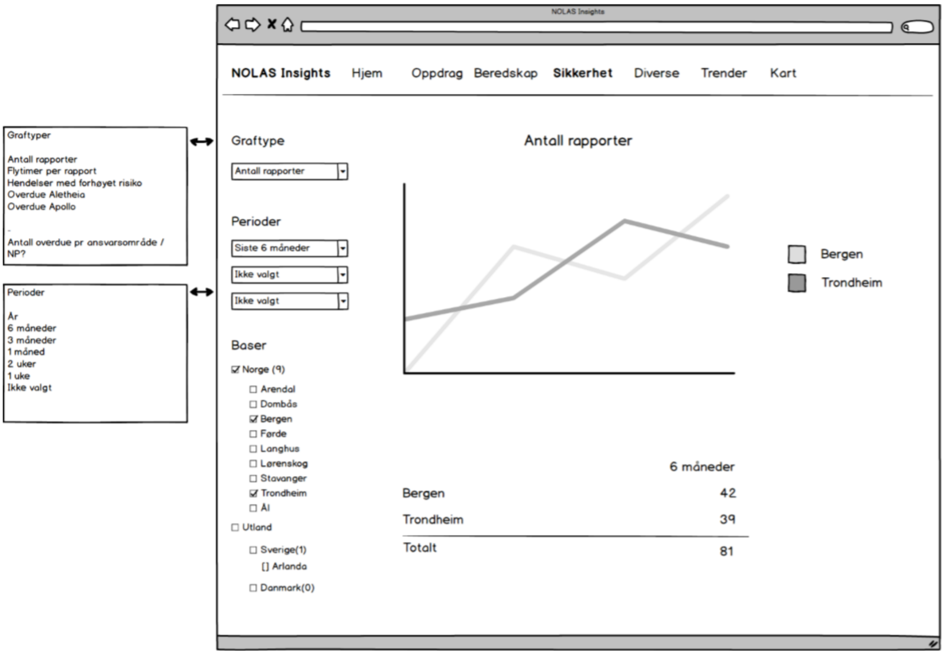


Figure B.5: Prototype I - the security page.

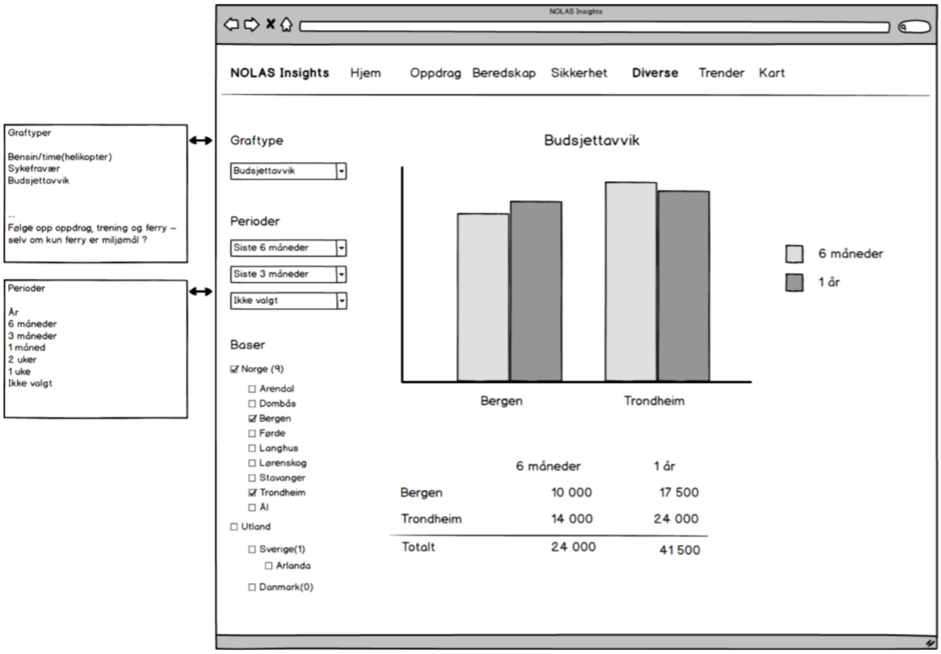


Figure B.6: Prototype I - the miscellaneous page.

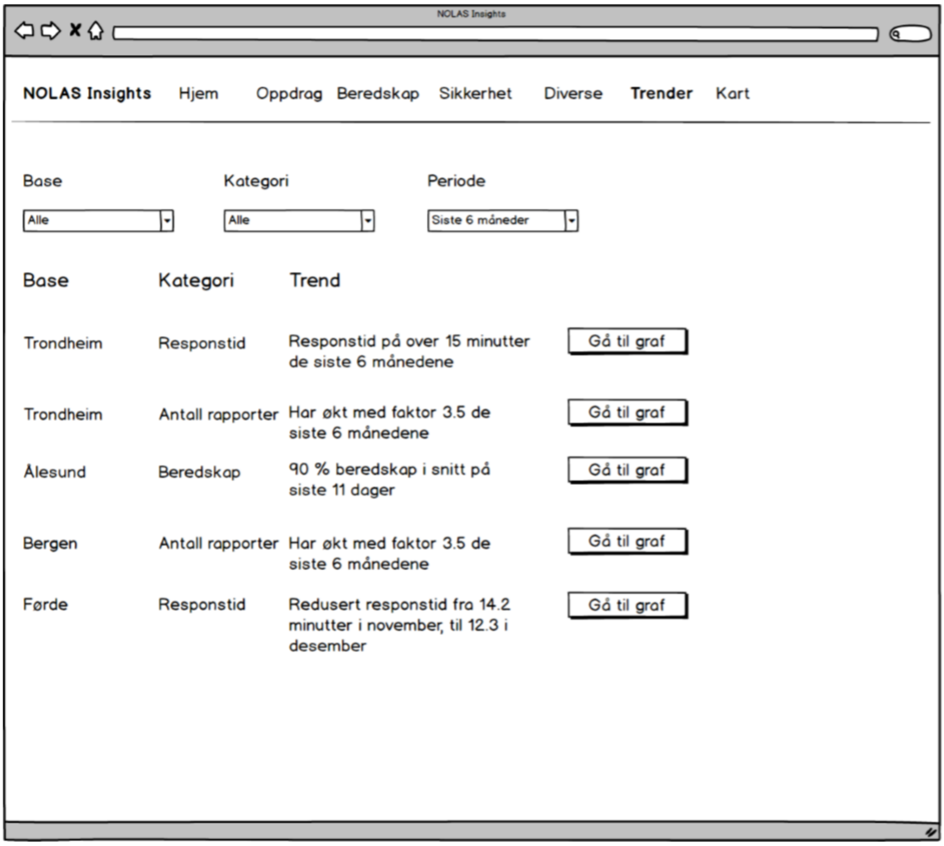


Figure B.7: Prototype I - the trends page.

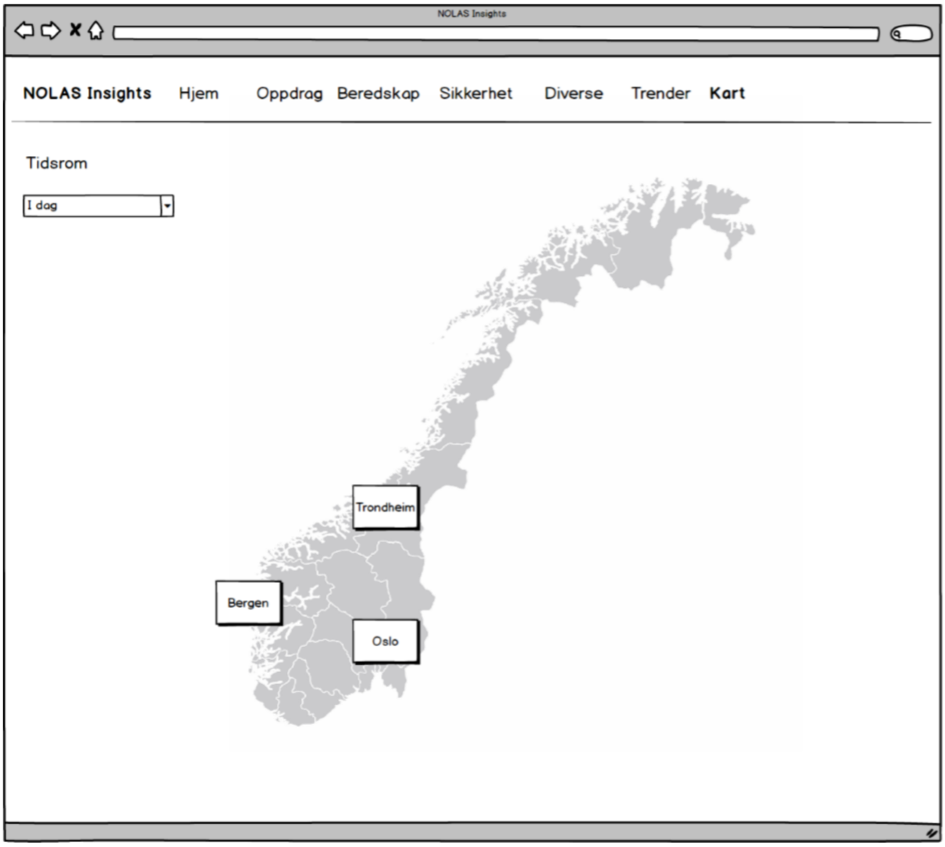


Figure B.8: Prototype I - the map page

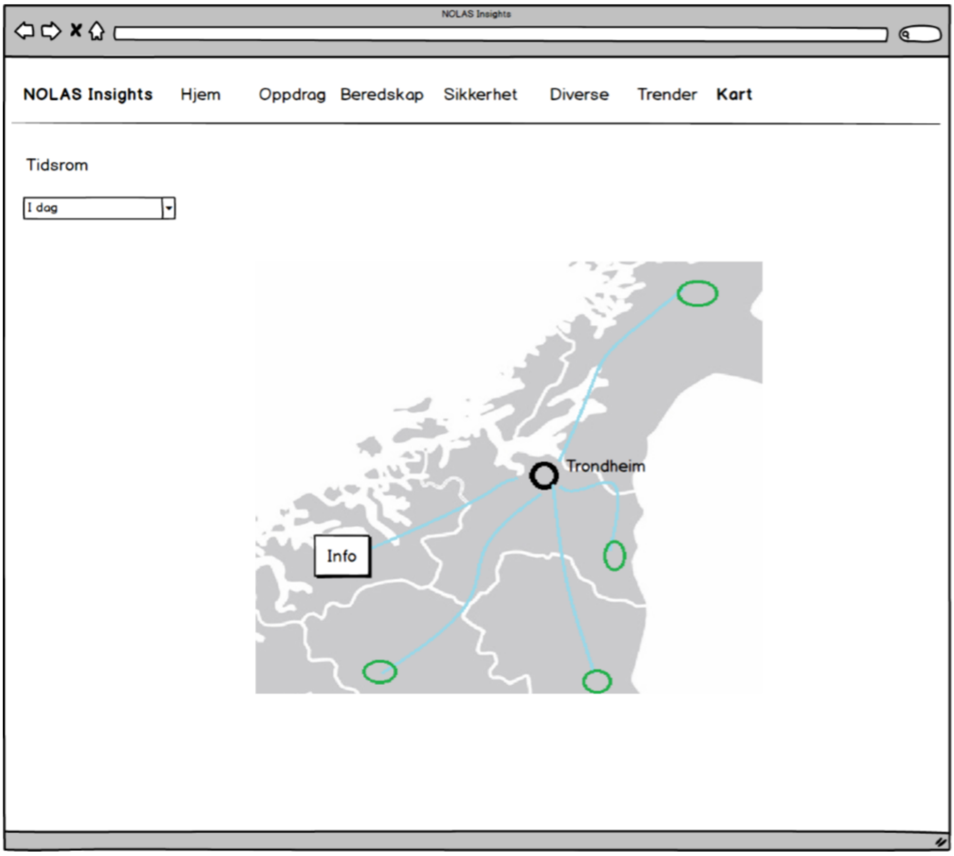


Figure B.9: Prototype I - a zoomed map representing the last day's missions in the area. Clicking on the info box opens up details about the mission.

B.1.2 Tasks in user test

1. Log in.
2. Find out how many missions there has been during the last week.
3. Find the latest trends about response time in the Trondheim base.
4. Locate the graph visualizing the response time trend.
5. Remove the Bergen data from the graph in order to only display Trondheim data.
6. What has the average response time been in Trondheim in the last year?
7. Is the response time best in Trondheim or Bergen?
8. Find statistics about the missions.

9. How many missions were executed in Bergen and Trondheim in the last 3 months?
10. Go to the security category.
11. Explain how you would approach finding similar security statistics to what is currently being graphed.
12. Go to the map category.
13. Find more details about the missions in Trondheim.
14. Find details about one of the missions.

B.1.3 Guidelines for the semi-structured interview

1. What do you think about the prototype?
2. Was anything unnecessarily difficult?
3. Was anything inconsistent or was there anything you would like to do in another way?
4. Did you think the system was easy to use?
5. How often do you have the need to use a tool like NOLAS Insights?
6. What functionality in NOLAS Insights do you think will be most useful?
7. How do you want to be able to compare data?

B.2 Prototype II

B.2.1 Screenshots

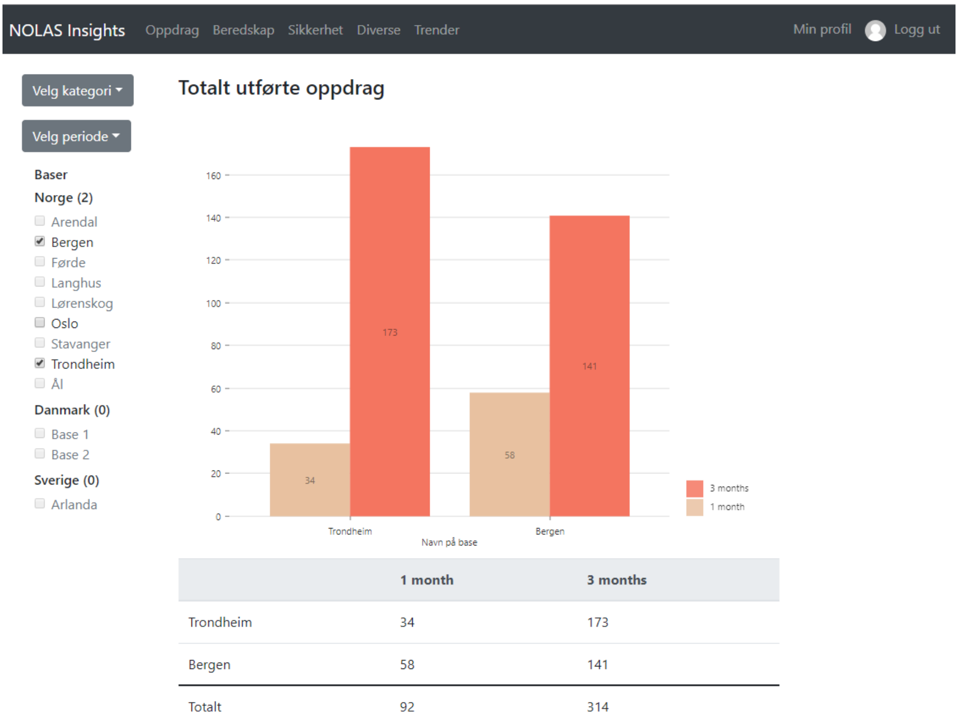


Figure B.10: Prototype II - overall showcase of design.

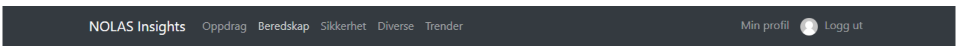


Figure B.11: Prototype II - menu providing navigation to the categories: dashboard (clicking NOLAS Insights), mission, contingency, security, miscellaneous, trends, and an user page.

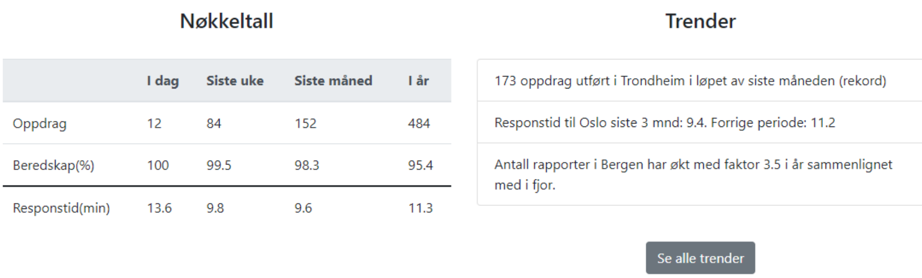
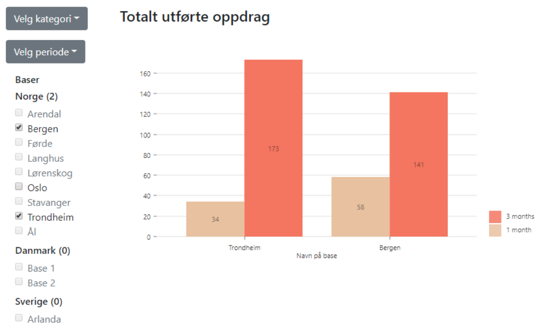
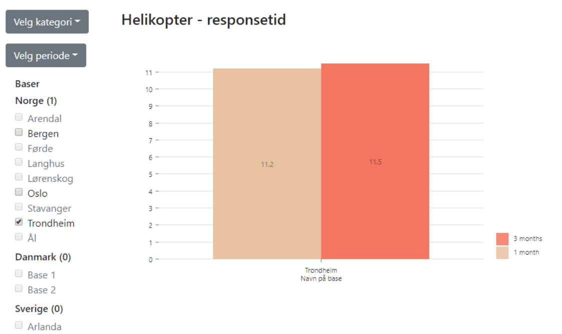


Figure B.12: Prototype II - a dashboard showing important statistics on the left and recent trends on the right.



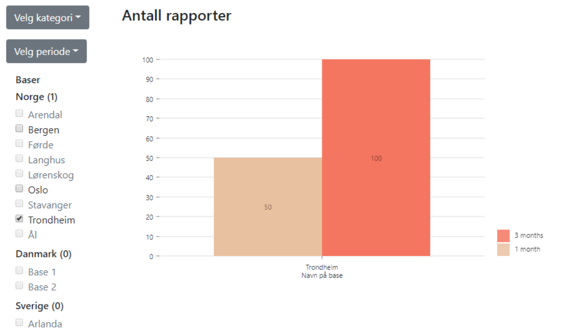
	1 month	3 months
Trondheim	34	173
Bergen	58	141
Totalt	92	314

Figure B.13: Prototype II - the activity page showing a comparison of the number of executed missions in two bases in the last 1 and 3 months.



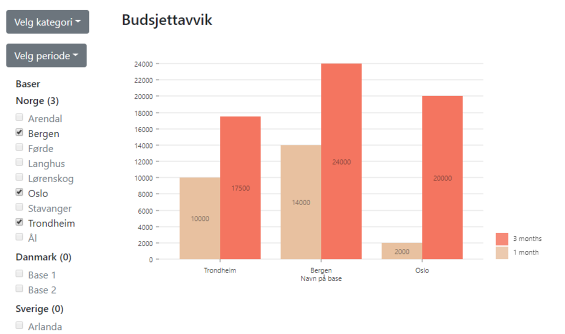
	1 month	3 months
Trondheim	11.2	11.5
Totalt	11	11

Figure B.14: Prototype II - the contingency page comparing the response time in Trondheim in the last 1 and 3 months.



	1 month	3 months
Trondheim	50	100
Totalt	50	100

Figure B.15: Prototype II - the security page comparing the number of reports in the last 1 and 3 months.



	1 month	3 months
Trondheim	10000	17500
Bergen	14000	24000
Oslo	2000	20000
Totalt	26000	61500

Figure B.16: Prototype II - the miscellaneous page comparing budget deviations in 3 bases in the last 1 and 3 months.

Figure B.17: Prototype II - the trend page showing various trends with a link to a visual explanation.

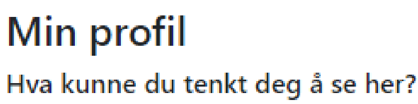


Figure B.18: Prototype II - the user page only used to facilitate discussion about what the user would expect to see there.

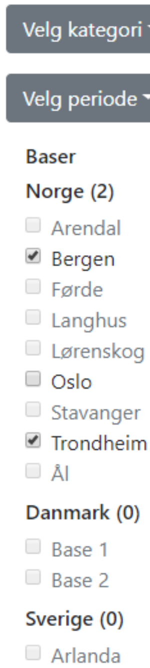


Figure B.19: Prototype II - the available filters. The prototype supported picking different graph types and bases, but each page had the hardcoded period selection to be the last 1 and 3 months.

Figure B.20: Prototype II - the login page.

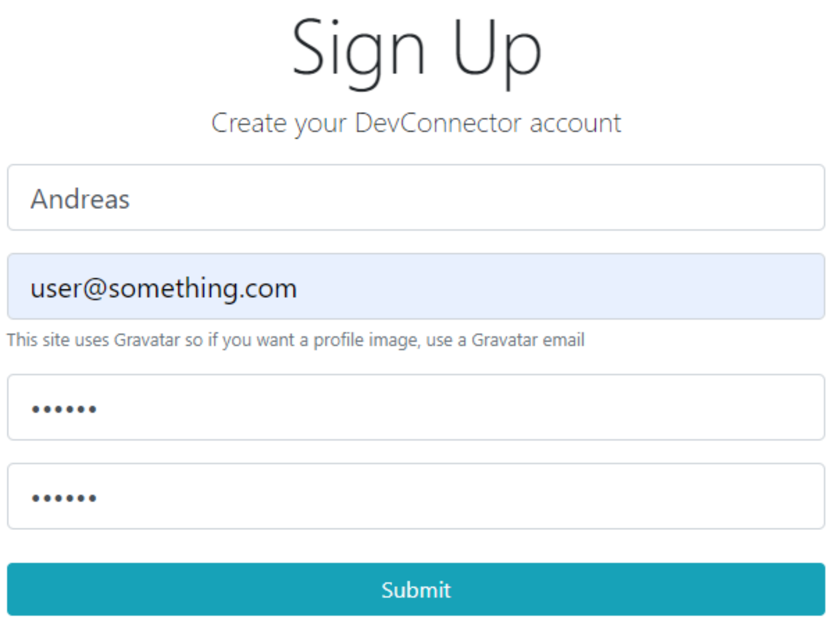


Figure B.21: Prototype II - the registration page. Some boilerplate code remain as can be seen in the picture.

B.2.2 Tasks in user test

1. Log in.

2. Find the number of missions done today.

3. Find a list over all trends.

4. Show how you would approach finding a trend of a specific type.

5. Find the number of missions that have been executed in Trondheim and Oslo in the last month.

6. How many missions have been executed with helicopter in Bergen in the last 3 months?

7. Which base has the best response time in the last 1 and 3 months respectively?

8. What is the total budget deviation for Bergen and Oslo in the last month?

9. Find information about your user.

B.2.3 Guidelines for the semi-structured interview

1. What do you think about the prototype?
2. Was something inconsistent or would you do something differently?
3. What is this system lacking the most?
4. How do you want to compare base data? With regards to data categories, bases and time frame.

B.3 Prototype III

B.3.1 Screenshots

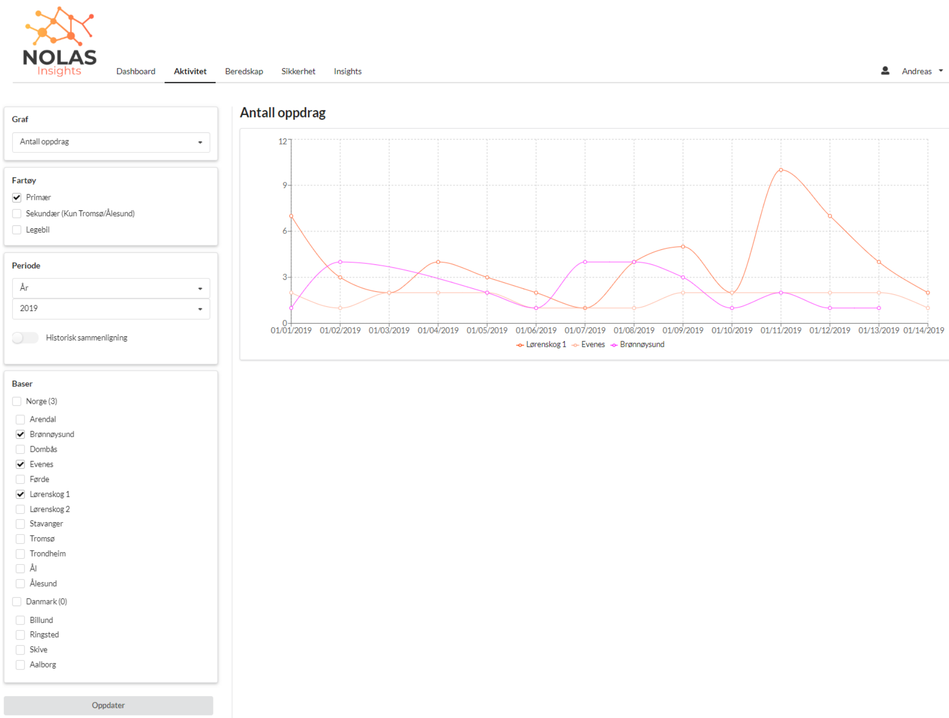


Figure B.22: Prototype III - overall showcase of design.

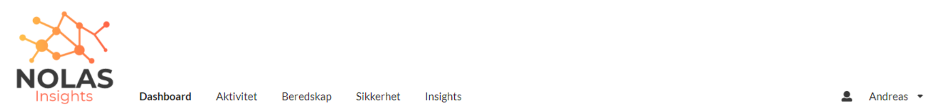


Figure B.23: Prototype III - menu providing navigation to the categories: dashboard, mission, contingency, security, insights, and a user page.

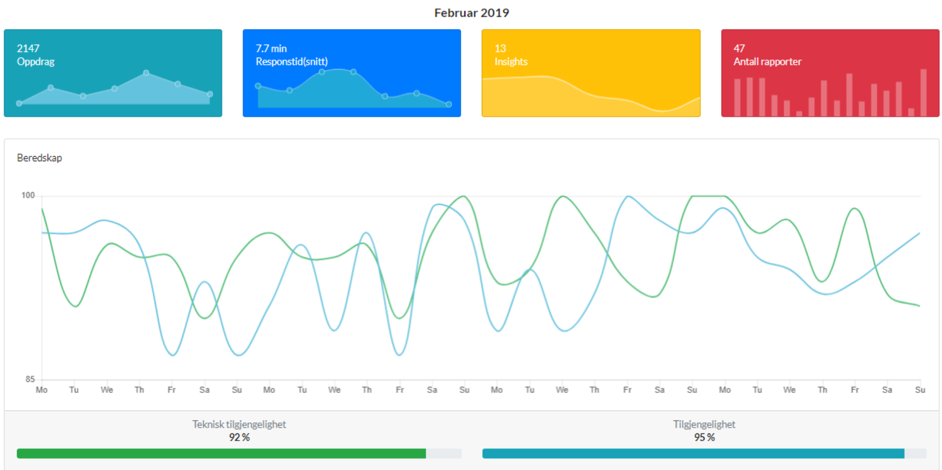


Figure B.24: Prototype III - the top part of the dashboard showing key statistics and a visualization of the average availability in all bases.

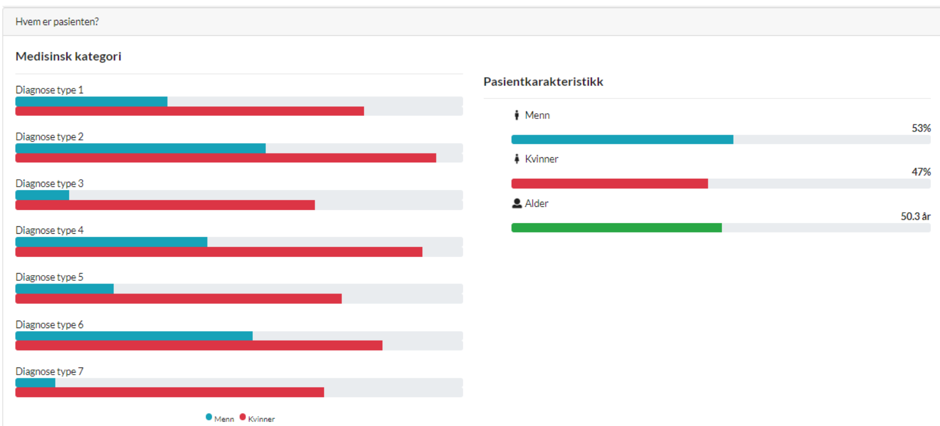


Figure B.25: Prototype III - the middle part of the dashboard showing characteristics about the patient.

Figure B.26: Prototype III - the bottom part of the dashboard showing statistics about the users of the system and social media.

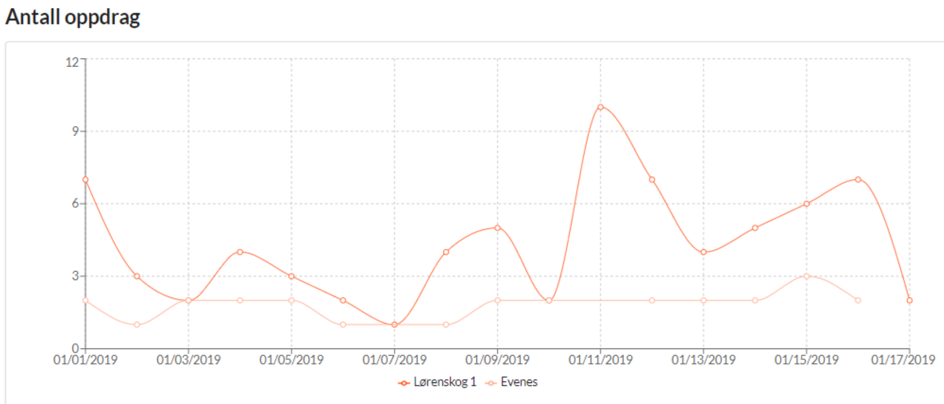


Figure B.27: Prototype III - the activity page showing a comparison of the number of executed missions in two bases in January 2019.

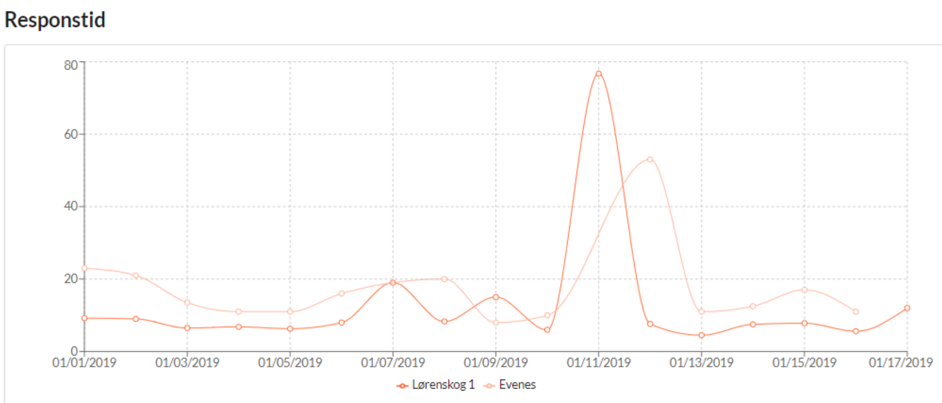


Figure B.28: Prototype III - the contingency page comparing the response time in Trondheim in the in January 2019.

Figure B.29: Prototype III - the security and insights pages were not implemented and a graphic was used to indicate that they were in development.

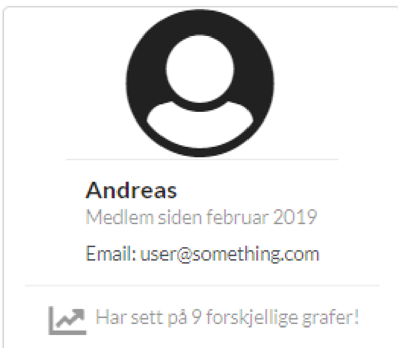


Figure B.30: Prototype III - the user page showing basic info about the user and the number of graphs they created.

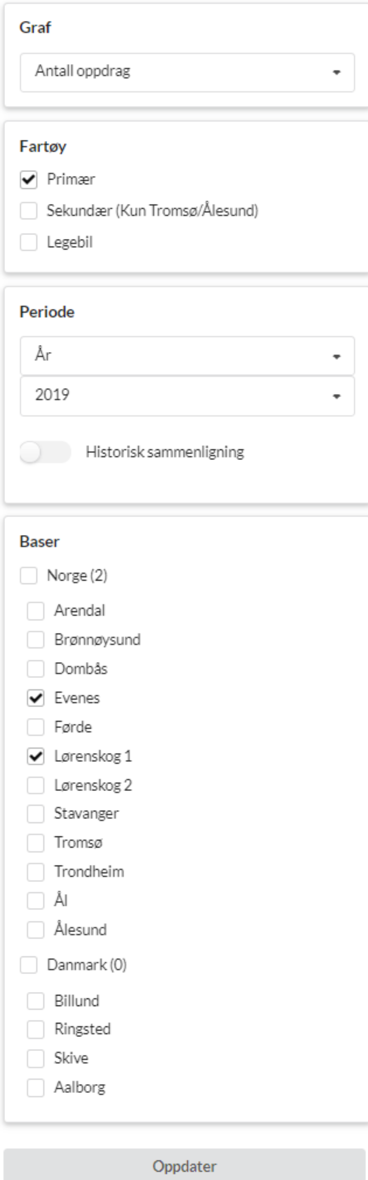


Figure B.31: Prototype III - the available filters. The prototype supported picking different graph types, bases, and periods. The button was used to update the graph.

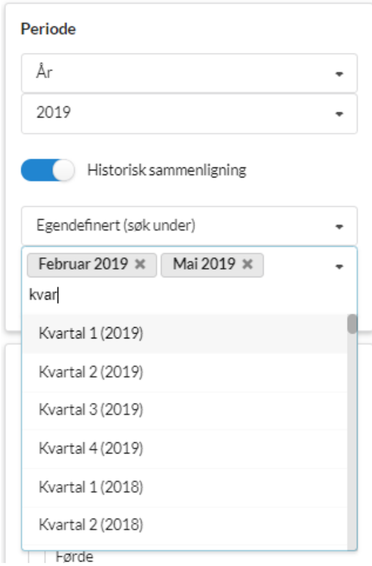


Figure B.32: Prototype III - the period filter with historic comparison enabled. The main period types are month, quarter, year and all time. The user can search and select any type of periods to compare with the main period.

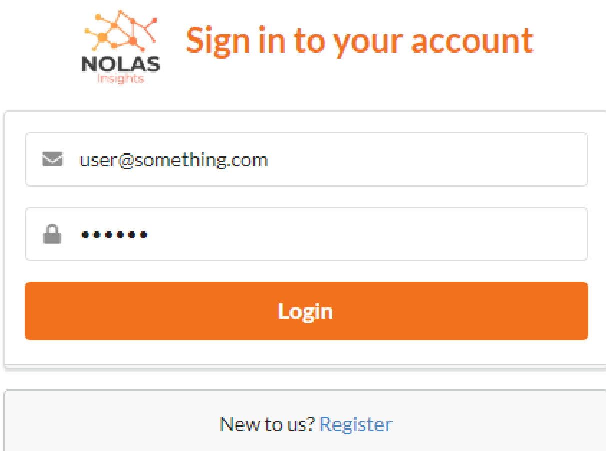


Figure B.33: Prototype III - the login page.

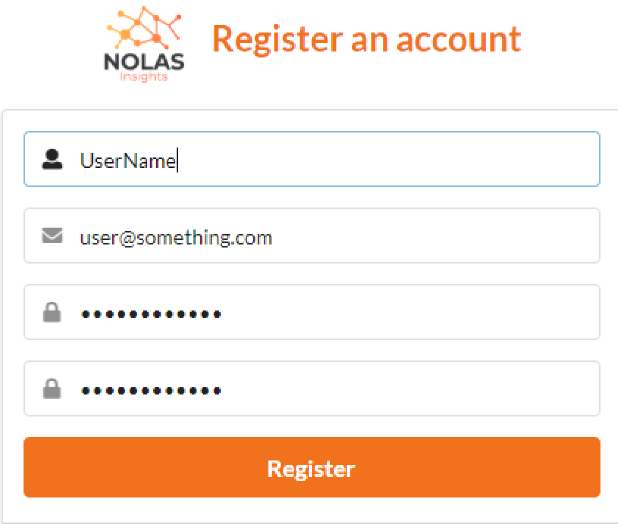


Figure B.34: Prototype III - the registration page.

B.3.2 Tasks in user test

1. Make a user and log in.

2. What do you find the most interesting here? (viewing the dashboard).

3. Find the number of reports filed in February.

4. Find the technical availability in February.

5. Find the number of followers the Norwegian Air Ambulance Foundation has on Twitter.

6. Which user of the system has created most graphs?

7. Display a graph with the number of missions in Trondheim and Stavanger in 2017

8. Find the number of missions that were executed April 7th 2018 in Dombås, Evenes and Lørenskog 1.

9. Find a representation of the response time for bases in Norway

10. Find a representation of the response time for Danish bases in quarter 2 2015.

11. Find the number of graphs you have created so far

B.4 Prototype IV

B.4.1 Screenshots

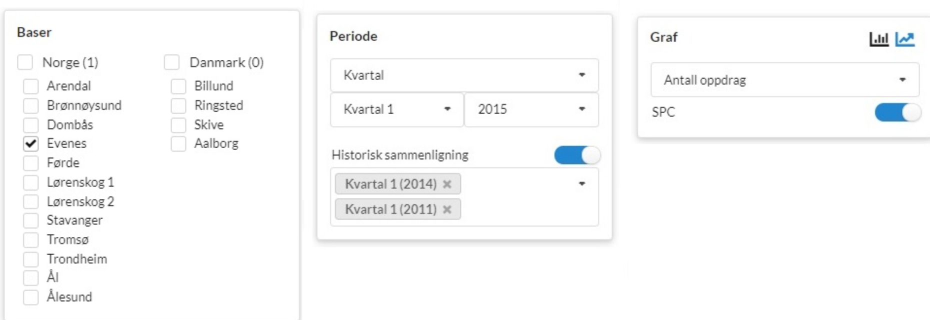


Figure B.35: Prototype IV - the current status of the filters.

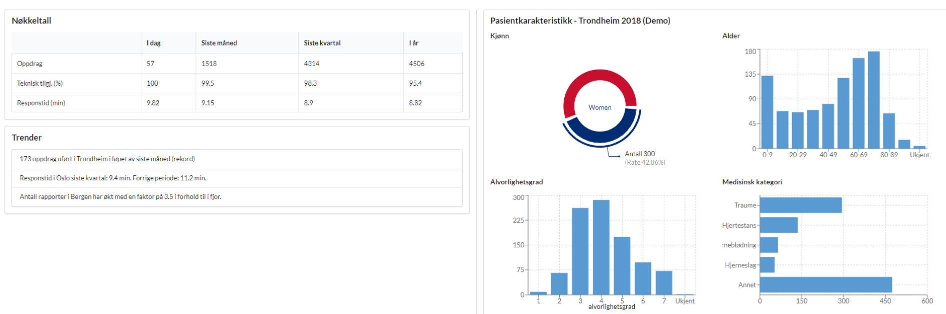


Figure B.36: Prototype IV - the insights page.

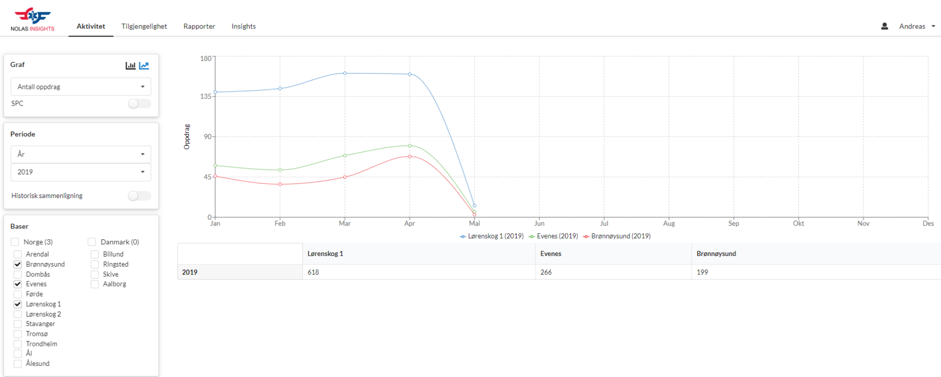


Figure B.37: Prototype IV - the graph showing the operational overview.

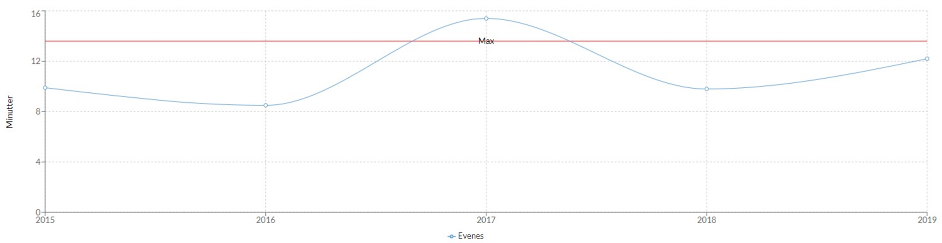


Figure B.38: Prototype IV - the graph showing current process control implementation.

	Brønnøysund	Lørenskog 1	Billund
Kvartal (Q1 2019)	128	445	285
Kvartal (Q1 2018)	0	406	360
Kvartal (Q1 2016)	0	407	278
Kvartal (Q1 2014)	0	376	0
Kvartal (Q1 2011)	0	405	0

Figure B.39: Prototype IV - the table showing quarterly data for three bases.

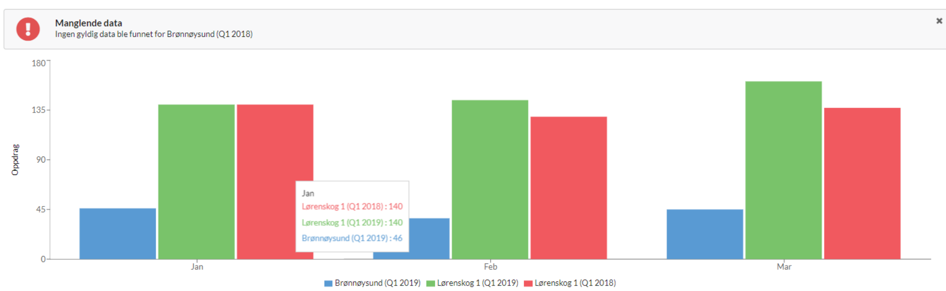


Figure B.40: Prototype IV - the bar graph view.

B.4.2 Tasks in user test

1. Register using an invitation link
2. Log in
3. Use the graph to determine whether Evenes or Lørenskog 1 had the most registered missions in June, 2017.
4. Use the table to determine which one of these bases had the most registered missions in 2017.
5. Change to a bargraph view.
6. Find the development of number of mission in Q2 in 2016 in all bases in Denmark. Do you notice anything special using this filtering?
7. Find a yearly overview of the response time from 2015 to 2019 in Evenes. Which year has the highest average response time?
8. Look at the bases Førde and Evenes. Compare May in 2017 with 2016 and 2015. Which day had the lowest technical availability?
9. Which base in Norway had the lowest total availability in Mars in 2018?
10. Is there more women or men that have been treated on the base in Trondheim in 2018?
11. Which age group was most at risk?
12. Not including categories that are unregistered, which medical category has the highest number of incidents?
13. What is the average response time this year?
14. What is the most interesting trend?
15. How many users are there in the system?
16. How many graphs have you created in the system?
17. Invite a new candidate to the system.

B.5 Final prototype

B.5.1 Screenshots

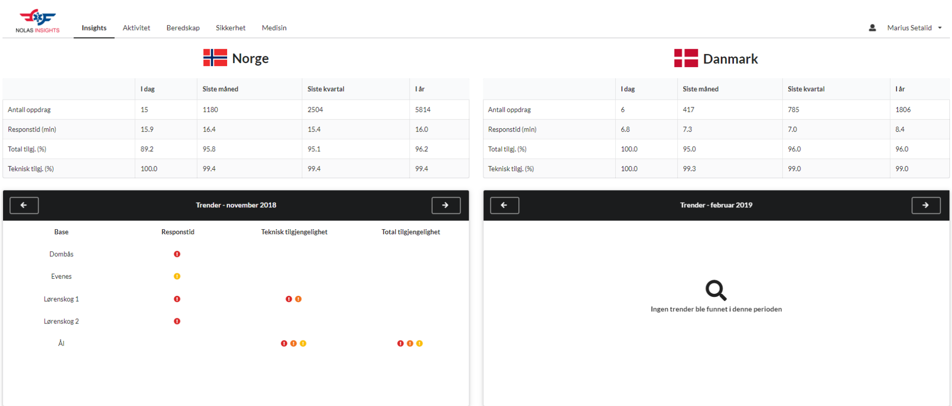


Figure B.41: Prototype V - the home page showing key numbers and trends.

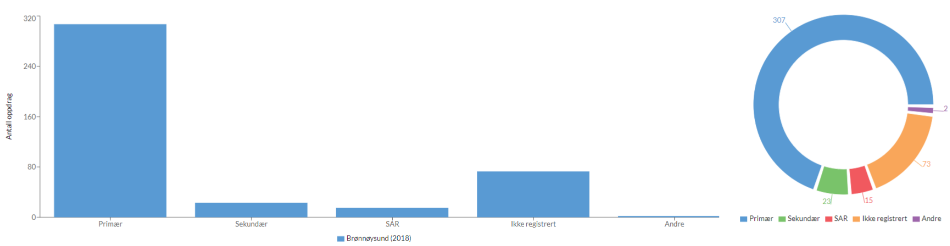


Figure B.42: Prototype V - the distribution graph showing the distribution of types of missions.

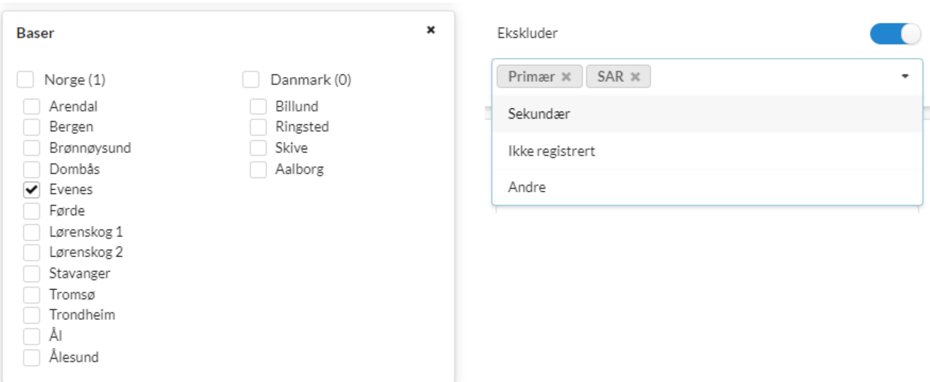


Figure B.43: Prototype V - the base and exclusion filter.

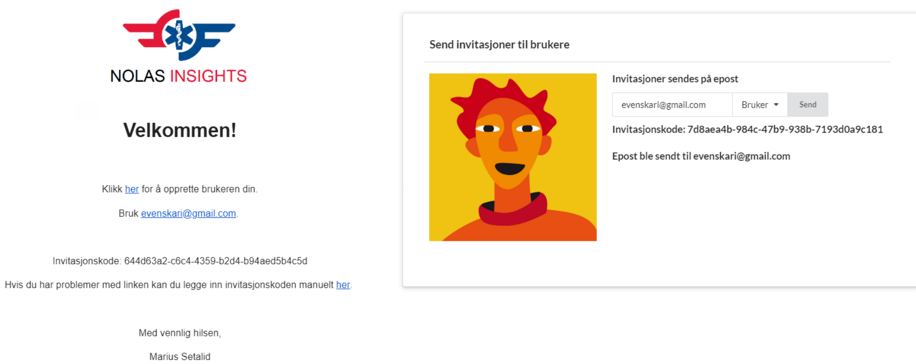


Figure B.44: Prototype V - the generated e-mail and invitation modal.

	Dombås	Evenes	Total
2017	99.6	98.6	99.1
2018	99.1	99.1	99.1
Total	99.4	98.9	99.2

Figure B.45: Prototype V - the table showing yearly statistics for two bases.

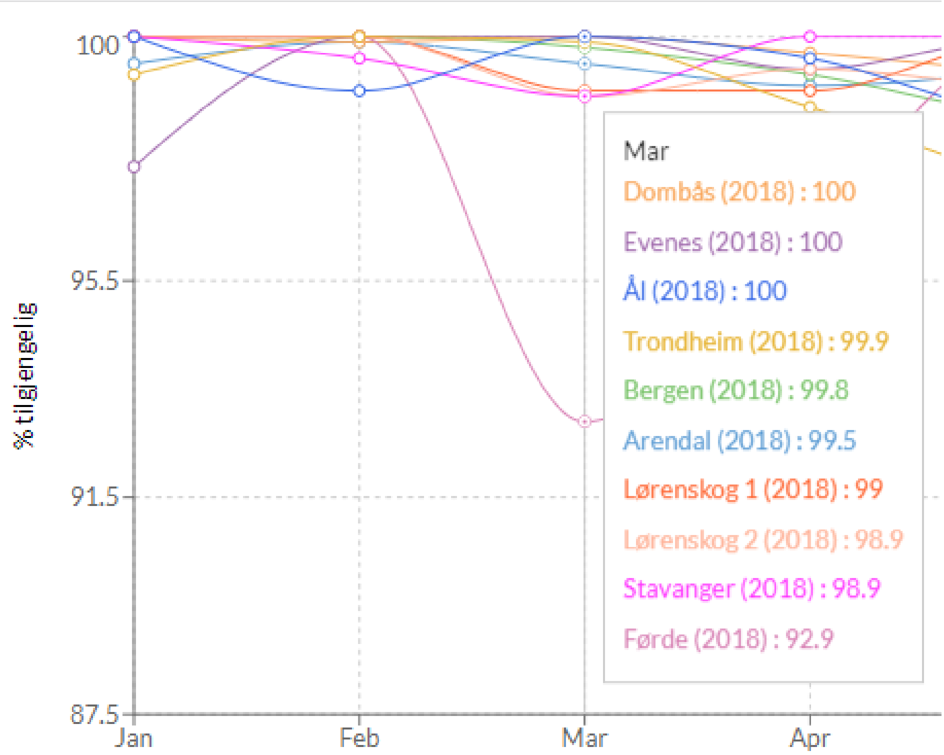


Figure B.46: Prototype V - the sorted tooltip.

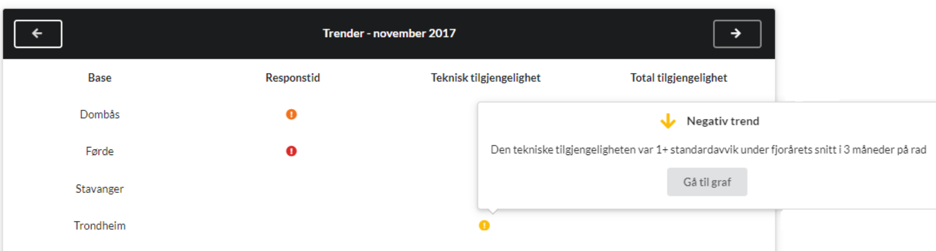


Figure B.47: Prototype V - the trend tip that appears on hover.

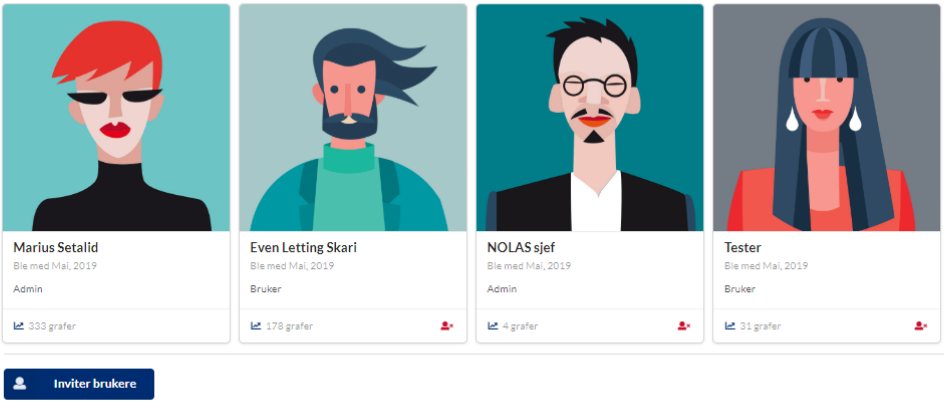


Figure B.48: Prototype V - the user page.

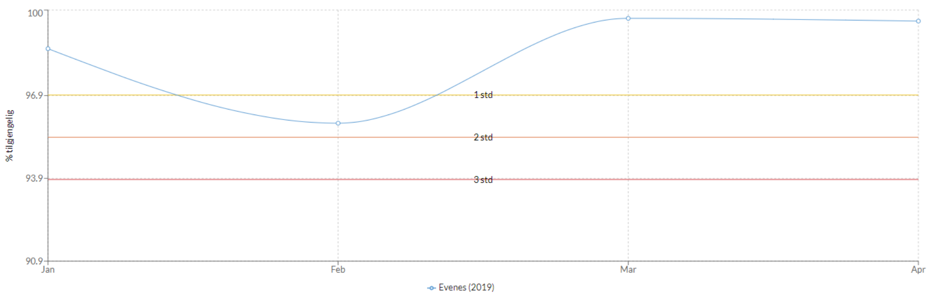


Figure B.49: Prototype V - a graph showing three standard deviations off the yearly average.

B.5.2 Tasks in user test

1. Identify what you can see in the top table. What numbers do you think are most interesting?
2. Has there been any trends in Norway in February, 2019?
3. What bases are there in the trend section and what kind of information do the trends tell you?
4. Can you find a graph concerning the air time?
5. Can you show the air time in Q2, 2017?
6. Can you compare this with Q2 in 2016 for Trondheim and Arendal?
7. Can you exclude the secondary missions?
8. Can you now find the total airtime combined in these two bases in these two periods?

9. Find a graph of the response time.
10. Look at the year 2019 so far in Lørenskog 2 and Ålesund.
11. Is the response time in any of these four months outside acceptable deviation?
12. If true, for which bases and which months?
13. Which role do you as a user have in the system?

B.5.3 Guidelines for the semi-structured interview

1. How easy is this system to learn in relation to other systems?
2. How easy is the system to use?
3. Will this system be useful for you? If no, what is missing?
4. To what degree does the system visualize operational characteristics and trends?

B.5.4 Demo

A demo of the final prototype is made available to graders of the thesis. The demo is not linked to NAA's system and no harm can be done by testing the demo system. The demo is hosted on a free Heroku server. Expect some time to load the system initially, as the server takes some time to return from the idle state. The system will be taken down once the thesis has been graded.

Use the information below to open and log in to the NOLAS Insights demo.

Link: https://nolas-insights-sensor.herokuapp.com/

Email: snillsensor@gmail.com

Password: sensor123

Marius Setalid and Even Letting Skari

NOLAS Insights

NTNU
Kunnskap for en bedre verden