30th Annual INCOSE international symposium
Virtual Event
July 20 - 22, 2020

# Design Thinking and Systems Engineering to Map Human Needs and Improve Digitization at an Emergency Health Care – a Case Study

Jurate Schønning
University of South-Eastern Norway
Hans Brattebergs vei 153, 3610 Kongsberg
+4796666966
kovjur@yahoo.no

Kristin Falk
University of South-Eastern Norway
Postbox 235, 3603 Kongsberg
+47 97485909
kristin.falk@usn.no



**Abstract**. This study from out-of-hours emergency primary health care investigates methods to improve the digital solutions to become both effective and empathetic. A relatively small inter-municipal emergency care in Norway struggles with high costs and low efficiency. Employees spend a lot of time performing various manual work that is of little benefit to patients. We used the steps from Design Thinking and tools from Systems Engineering to come up with an improved solution. Furthermore, we tested this solution on staff at the emergency room.

The study shows that the current computer tools clearly lack functionality when it comes to meeting the needs of employees such as efficient operation and facilitation for good patient flow. Employees felt that complicated digital tasks steal time that could be better spent on health care. Furthermore, the employees lack a comprehensive overview of systems functionality.

We have proposed several innovative functional improvements, including interaction technology in the form of a wall-mounted work board, which according to the employees will enable streamlining of tasks at the emergency room. These solutions have emerged by using a step by step, iterative and structured system technique inspired by Design Thinking. Extensive interaction with the systems users throughout the project phase has enabled us to clearly understand the challenges of the emergency room and associated solutions. We believe that empathy with the users is essential in innovative digital solution.

## Introduction

The control of a complex system must be based on a comprehensive understanding of the interaction between the elements as well as take the necessary measures to ensure efficient operation (Reid PP et al. 2005). Since health care depends to a great extent on humans, control in the health care system is tied to the correct use of labor resources. This paper uses Design Thinking techniques as a supplement to Systems Engineering processes to obtain an understanding of how labor resources can be better utilized to deliver health services.

**The Norwegian emergency care system** shall provide advice and guidance on inquiries for immediate assistance. Furthermore, it shall diagnose and treat acute medical conditions during doctor consultations and visits, and if necessary refer to other services in the municipality, including a general practitioner and specialist health services.

**The Kongsberg Inter-Municipal Out-of-hours Emergency Primary Health Care (Emergency Care)** is located in Norway. The Emergency Care has approximately 20 full-time equivalents distributed to administrative staff, nurses and doctors and temporary staff, as well as 55 affiliated GPs providing emergency medical services. It has 24-hour continuous operation and offers the fifty five thousand inhabitants assistance in the event of acute injuries, illnesses and crises, from the new customized emergency rooms. The Emergency Care works closely with Kongsberg Hospital, with which they are otherwise linked, via a corridor. The Emergency Care serves three municipalities. The three municipalities recently merged their emergency in order to comply with the emergency medicine regulations on good emergency care services with the right expertise and enough capacity and services. The owners expect the merged medical wardens to achieve economies of scale in the form of increased service levels as well as reduced expenses per treated patient.

This paper primarily covers the voice of the health personnel in the Emergency Care. The background for this work was economic constraints, and a need from the management to improve the effectivity. The economic constraints is a background, but not the focus of this paper.

**Digitization** is proposed by the management to further develop the Emergency Care. By digitization we mean all tools controlled by digital instruments, including automation solutions controlled by digital tools. The employees were barely involved in the digitization initiatives when the Emergency Care built new customized emergency room in 2016. The employees were only consulted in connection with the number of computers and the location of these. Furthermore, the employees were involved in choosing whether to use projectors or LCD monitors as presentation screens as well as the degree of automation of the medicine room. Beyond this, the employees were neither interviewed nor observed.

**Case.** Understanding stakeholders' *human needs*, including their emotional needs, is important when introducing new digital solutions. This article uses the Kongsberg Emergency Care as a case as it attempts to answer the following question:

- "How can Design Thinking and Systems Engineering methods be used to map human needs and improve digitization at the Emergency Care?"

**Approach**. Using the Design Thinking technique, we have identified needs that have formed the basis for digitization solutions that benefit the emergency room operation. We conducted observations, interviews and surveys as well as mapped trends and innovative digitization solutions. Furthermore, we have searched through articles and books that have a Systems Engineering perspective related to research within health institutions. Based on analyzes of information obtained, we have prepared specific proposals for improvements to digitalization solutions at the Emergency Care.

## Background - Health Care Systems

**Lack of Involvement.** Former research (Seehusen, 2019) indicate that doctors find it strange that they are not involved in the design of computer systems. Seehusen emphasized that health professionals complain that they spend a lot of working time to fill out forms, scan documents and apply slow computer systems. The importance of involving employees in the implementation of new technology in the health care system is underlined by Jære (2017). Jære argued that there are major financial benefits and increased well-being associated with involving health professionals in choosing technological solutions.

**Interdisciplinary**. According to (Maher, 2007) at the Centers for Quality Development, Region Jutland, for employees to be successful in health care it is important that the employees are involved, that the changes are adapted to the organization, and that the benefits are real. Furthermore, Maher emphasized that interdisciplinary participation is essential for health care improvement projects to be successful.

**Quality requirements in the health care system.** The nonprofit Institute of Medicine (IOM) affiliated with the US National Academy of Science has defined six quality goals for good hospital operation. These quality goals are, patient safety, efficiency based on scientific methods, patient-centered, time-efficient, resource conservation and fair operation. Promoting these quality goals, according to (Hollnagel et al. 2005), requires understanding the needs and performance goals of all stakeholders as well as necessary balances between stakeholders.

**Economical**. The SamKAD project developed solutions for new digital interaction technology and various applications. In the innovation project SamKAD at the Aker Health Arena, health workers collaborated with Industry. The final report (Ausen et al. 2017) emphasizes that the operation became more economically efficient. Ausen emphasized that the innovation project has contributed to saving time, better interaction and more efficient operation, which is taken out in more patient-oriented time and better quality and services. Furthermore, Ausen emphasized improved user experience.

**Reduced empathy.** According to the article "Nurses Must Learn to Say No" written by (Rune Langnes, 2015) in the Nurse Magazine, health workers often work under time pressure. At the same time, the health workers must treat the patients professionally and compassionately. According to Langnes, this can cause stress, which is substantiated by (Herbert Freudenberger, 1974) as a research on burnout, in which he described symptoms such as lack of commitment, energy and general fatigue among health care workers. Furthermore, (Hooper et al. 2010) revealed that health professionals experience dissatisfaction by working in a work environment where one feels that one is not stretching, and that this may put a strain on the emergency room staff. Furthermore, Hooper has looked more closely at the prevalence of empathy, burnout and compassion-fatigue among nurses in the acute health care system. The study concludes, among other things, that emergency-room nurses have an increased risk of reduced empathy.

**Innovation based on empathy, interdisciplinary and prototyping**. Three important aspects of Design Thinking in the healthcare system are (1) empathy with health professionals and patients, (2) interdisciplinary collaboration, and (3) rapid development of prototypes (J. P. Roberts et al. 2015). For product solutions to be useful, all stakeholders must have a clear understanding of the challenges to be addressed.

# Research Methods

## *Methods and Tools*

The method framing this research is a five-step Design Thinking process with a focus on human-centered design. In addition, the research applies tools from Systems Engineering such as context diagrams, and quality tools including Root-cause analysis, Pareto Diagrams, 5Why.

**Human-Centered Design (HCD)**.The standard (ISO 9241-210, 2010) for human-system interaction defines HCD, "as a method to make systems more user-friendly by focusing on the users of the system". It is also emphasized that well-developed systems adapted to users will improve productivity and improve well-being, reduce stress, simplify the user interface and reduce the risk of health damage.

**Design Thinking** can be illustrated as a five-step process (Plattner et al. 2009). In its attempt to describe Design Thinking, (Lockwod 2010) states that Design Thinking is a human innovation process that emphasizes observation, collaboration, rapid learning, visualization of ideas and rapid prototyping, based on the company's analyzes. Similarly (Brown, 2009) defines Design Thinking as a user-centric approach that balances the customer's workload, business value and feasibility repre-

sented by technological solutions. Both of these definitions form the basis for creating solutions that meet the customer's needs, while at the same time having to be commercially viable.

**System Enginering**, similarly, has as its goal to create products that create real value for the customer. Therefore, the starting point is what is the need that is wanted to be solved, while at the same time understanding the culture and context in which a new solution is to be implemented. A context diagram (A. Sols, 2014) can be of valuable help to achieve this.

**Root cause analysis** is used when the underlying causes of a problem are to be identified (The Supervisor of Root Cause Analysis, 2015). Those involved in a root cause analysis are persons who are affected by the issues that are highlighted, as well as in the measures that can solve the problems. This involvement of the affected parties, according to (The Root Causes Analysis Supervisor), entails ownership among employees of the solutions to deal with the problem. When identifying the root causes, several techniques or a combination of several techniques such as 5Why and Pareto Diagram can be used.

**5 x Why (5Why).** The 5Why technique is a questioning technique where you ask the question: Why repeatedly, until you get an answer to what lies at the root of the problem. The 5Why the questioning technique is most effective when the interview object has in-depth knowledge of the topic being interviewed. According to (Olivier Serrat: 2009) in the article "The Five Whys Technique" it is also important that the interviewer continues the question until the root cause is revealed.

**Pareto Diagram.** Pareto analysis is a mathematical method for identifying the problems that contribute most negatively and that are best exploited to eliminate. The analysis makes use of the mathematical fact that 80% of the problems are often caused by 20% of the causes. The Pareto principle states that in every group of conditions contributing to a common effect, a few of the conditions contribute to most of the effect (B. Nyen and M. Brudvik, 2010).

## *Step-Wise Research Approach.*

Our research methodology follows the Design Thinking steps outlined points 1-5 below. The Results and Analysis section presents the details for each step.

**1-Empathy.** The first step or phase required an empathic understanding of the issue that we considered. Empathic empathy was crucial. This phase gave us an understanding of the problem from the perspective of the involved.

**2-Define.** In the Define phase we structured, analyzed and synthesized the data we had observed and collected from the "Empathy phase". This is the problem definition phase where we identified the core issues. Tools from Systems Engineering such as Context diagrams, Root Cause Analysis, 5why and Pareto Diagrams aided in this work.

**3-Ideate.** The Idea Generation phase generated innovative ideas and solution. We applied the understanding gained in the Empathy phase, and the problem definition from the Definition phase. To reflect alternative ways of observing the problem, we used idea-generation techniques. The result was new ideas and solutions. It was important to generate as many ideas or solutions as possible.

**4-Prototype.** In the prototype phase, we prototyped simplified solutions. These solution were drawn, built or otherwise visualized to illustrate the idea. The purpose was to be able to reject ideas, improve ideas, conduct new investigations of improved ideas or accept ideas. In this way, we formed an understanding of how well the various proposals met the needs of the stakeholders, before preparing expensive full-scale products. At the same time the prototype helped in understanding the limitations and opportunities that the real user can encounter.

**5-Testing.** In the final phase, we tested the best solutions identified in the prototype phase. Ideally we should do iterations, changes and improvements to reveal a solution that meets the desired needs.

### *Limitations of Research.*

This research contains only one case, namely a single emergency center in a relatively small town. To account for this, we investigated former research. To a large extent, the former research confirms the validity of the problems we identified.

This study contains extensive interviews and tests with health care personnel. We did not interact with patients, nor across to other health organizations. The reason for this is two-fold, first, we sought a solution fit also for the nurses and doctors at the Emergency Care. Secondly, handling patient feedback required even stricter confidentiality and data-handling procedures. This was out of the scope of this study. Nevertheless, it is certainly recommended as further work; investigating the whole network of stakeholders.

This research paper does not include the economic considerations of the proposed solutions. The management at the Emergency Care supported this work based on a need for cost-efficient solutions, especially in terms of operational cost. This has been an important need, but we have not prioritized the prototypes based on capital cost.

The main investigator is both a nurse and a systems engineer. This is beneficial to the designed solution, but might make it more difficult to replicate our data. The fact that the main investigator had a collegial relationship with the nurses and other employers at the Emergency Care might have resulted in more positive answers and responses than other researchers or engineers. We have tried to adjust for this using a Likert Scale (Carl J. Chimi, et al.2009). At the same time, the double role of the main investigator opens a world of empathy and competency that you need a transdisciplinary and well-functioning team to obtain in most cases.

## Results and Analyzes

The 5-step Design Thinking forms the structure of this section that has sub-sections on Empathy, Define, Ideate, Prototype, and Test. The case is the Emergency Care in Kongsberg.

### *Empathy Phase*

**Stakeholders.** In order to identify effective concepts, we first identify the business needs and overall requirements. In this work, the business stakeholders are an important source, and we have identified the section managers to reflect this need.

The Emergency Care serves patients, and the employees work to prepare for the best possible patient care. As a result, patients and staff are the ones who are most affected daily by the digitalization solution at Emergency Care. This research selected the employees to be the primary stakeholders for improving digitizing at the Emergency Care. The reason for this is that the section managers wanted us to improve the digitization at Emergency Care based on the employees' working lives. Here it is to be noted that with an extended mandate, it would be necessary to include the patients as primary stakeholders as well.

**Mapping needs (Understand).** To identify the human needs and desires for digitization, we conducted a survey of the employees. The questionnaire was distributed to 27 persons, of which 22 persons provided feedback (2 Section Manager, 16 Nurses, 3 Physician and 1 Secretary). In general, the employees at the Emergency Care have long experience, but there are also some newly qualified nurses. Table 1 shows an overview of the respondents.

Table 1 Overview of respondents at Emergency Care

| Participants | Roles | Experience |
|---|---|---|
| 2 | Section Leaders | 10 + years |
| 3 | Doctors | 10 + years |
| 16 | Nurses | 1 to 20 + years |
| 1 | Secretary | 10 + years |

**Assumptions**. The Emergency Care is a well-equipped emergency room, with a well-equipped laboratory. The Emergency Care has one treatment room and two observation rooms with associated equipment as well as a medicine room equipped at the hospital-level. In addition, the Emergency Care has two doctor's offices that are equipped with all the usual measuring equipment. Emergency Care also has access to Kongsberg Hospital's laboratory for performing special tests, including blood gases, as well as access to the radiology department for x-rays. In addition, Emergency Care has four municipal immediate aid beds.

**Nurses' working day.** The nurses at the emergency room answer telephone inquiries, whereby they make priority assessments (triaging) regarding further treatment. The result of these assessments may be that some patients be prioritized to an ambulance, while other patients may be encouraged to contact their General Physician (GP). At the same time, the nurses perform continuous assessments when the patient arrives at the Emergency Care. By taking blood tests, measurements and assessing the patient's symptoms, the nurses can determine the degree of urgency more accurately, thus determining who should be seen by a physician immediately and who can wait. When patients arrive by ambulance at the same time as there are patients with a high priority at the emergency room, the available emergency room resources can become scarce. This is because nurses need to continue to answer new phone calls, assess new patients, take new tests and perform examinations, observe the effects of treatment being given, see any changes in patients' condition, provide for further transport, and document what is being done. In addition, the nurses must assist the physicians as well as prioritize inquiries that come via the emergency network or the security alarm. It is also the responsibility of the nurses to bring samples to the hospital laboratory, and collect food in the hospital kitchen, as well as pick up and bring patients, beds and wheelchairs. Furthermore, it is also the responsibility of the nurses to make bills for the patients, as well as to ensure that the stocks are complemented with medicines and consumables.

**Digital tools at the Emergency Care (Observation).** Both doctors, nurses and administrative staff at the Emergency Care must log on to many digital tools to perform their work. These digital tools are designed to solve different functions, and are not compatible with each other. Some of these digital tools provide a link between patients and Emergency Care for communication or diagnosis. While other digital tools are pure reporting tools, used only by the employees. Based on observations in the empathy phase, we have prepared a Context diagram of the digital tools at the Emergency Care. See Figure 3. Each of the points in the green circles represents individual digital solutions/tools.

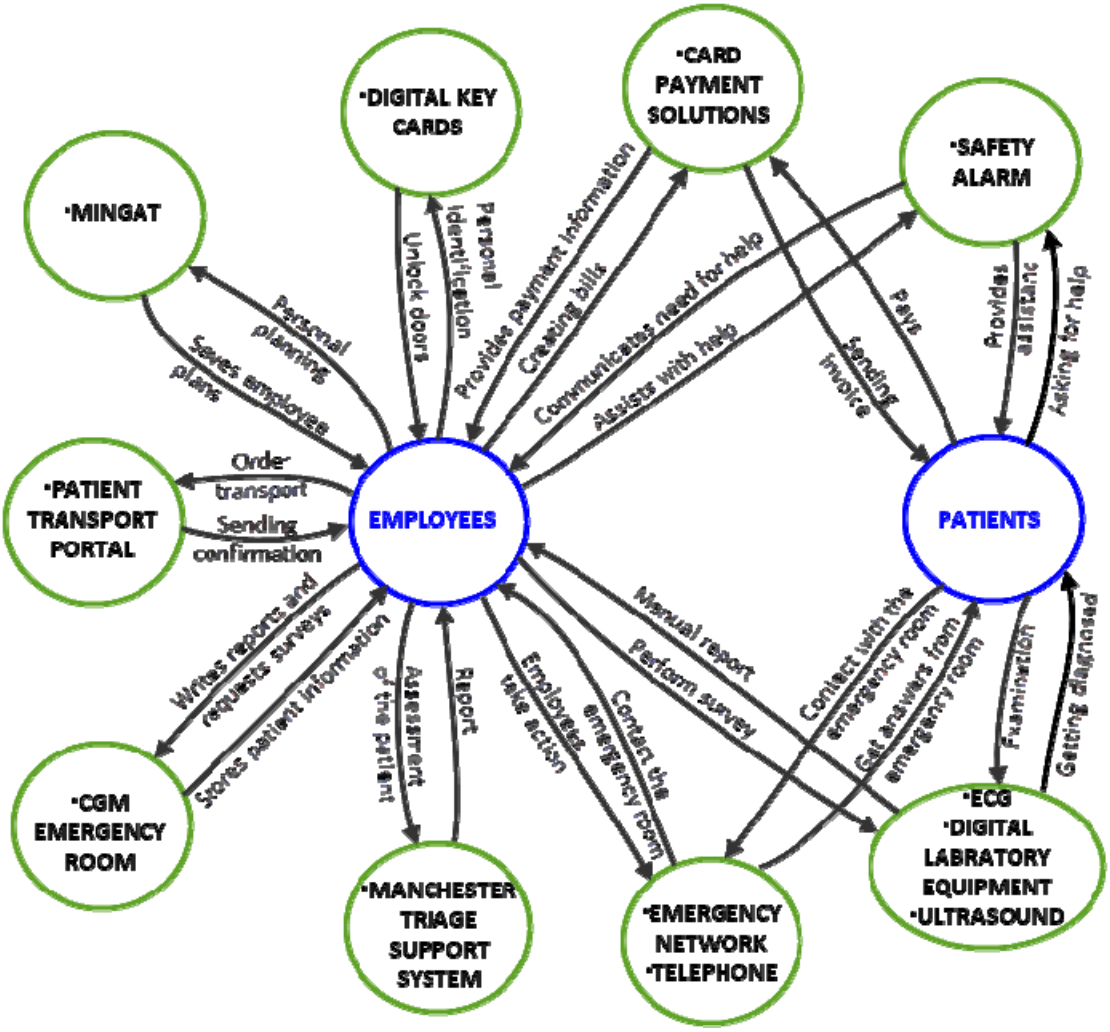


Figure 1 Context diagram of digital tools at the Emergency Care

**Challenges at the Emergency Care.** Despite the fact that the Emergency Care is new and adapted to operations, and that the patient-base has increased with the support of neighboring municipalities, the Emergency Care is operated without new innovative solutions. This means that the potential economies of scale have not been fully utilized. By adapting the digital solutions to today's opportunities and challenges, a holistic utilization of increased operational size and investments in new emergency room facilities will be better utilized.

Furthermore, employees claim to experience queues of patients, both on the telephone and at the Emergency Care. These queues are sometimes the challenging to handle, and are perceived as stressful for patients, relatives, and staff alike.

## *Defining Phase*

**Definition of problems.** In this phase we systematized the responses of the questionnaire regarding the respondents' wishes and needs for digitization and their suggestions for improvement. It emerged that several of the respondents had concurrent touch points. Ten different points of contact emerged, which in this article we call our main functions. Table 2 shows the needs of the respondents according to the main functions.

Table 2 Main functions, number of respondents and needs related to digitization at the Emergency Care.

| Main Functions | Number of respondents | Need for digitization at the Emergency Room |
|---|---|---|
| Ensure efficient & value-adding operation of the Emergency Care | 24 | - Get faster login on all data platforms<br>- Get faster data response<br>- Eliminating computer system failures (hanging, freezing and locking) |
| Register dialed patients | 11 | - Streamline recording of recorded patient data |
| Observe and treat | 12 | - Streamline registration of samples, vital, medications |
| Get medicines | 22 | - Streamline the management of prescribed medications<br>- Get a good overview of medicines in the medicine room |
| Keep track of Emergency Care operations | 40 | - Get a good overview of work tasks<br>- Keeping a good record of patient status<br>- Get a good overview of statistical measurements and reports for emergency room operations<br>- Get a good overview of equipment |
| Register patients on arrival | 8 | - Streamline registration of patients arriving at the emergency room |
| Communicate | 34 | - Get good, fast and secure communication between health care institutions, patients and staff<br>- Reduce time spent on diagnosis and observation of patients<br>- Improve overview of patient health data |
| Pick up and bring | 9 | - Get help when picking up and bringing patients, equipment, food, samples, etc. |
| Open doors | 3 | - Get easier passage at doors |
| Adaptation of work cells | 6 | - Easier ergonomic adjustment of chairs, tables and screens |

By removing work activities that are not value-adding, the working life of the emergency room workers will change so that physical and mental stress can be reduced. At the same time, the changes in the workload create an opportunity space to allocate working hours to activities that contribute to more versatile work tasks and increased coping skills. Likewise, patient satisfaction will improve with less waiting and increased quality of service, and thus contribute to increasing confidence in the emergency room service.

**5Why analysis.** Based on the main functions that emerged (Table 2), the main investigator performed a 5Why analysis together with 3 employees at the Emergency Care. The 5Why analysis revealed the core problems as lack of time and overview. All the main factors contains there elements directly or indirectly.

**Pareto Diagram.** To analyze the needs for digitalization at Emergency Care, we also carried out a Pareto-chart analysis. The Pareto analysis of the main functions in Table 2 indicated which needs will provide the best possible value for the employees. From the Pareto diagram in Figure 4, we see that 80% of the stated improvements are related to about half of the main functions. This means that we can implement improvements to as much as 80% of the indicated digitalization needs by focusing only on half of the main functions.

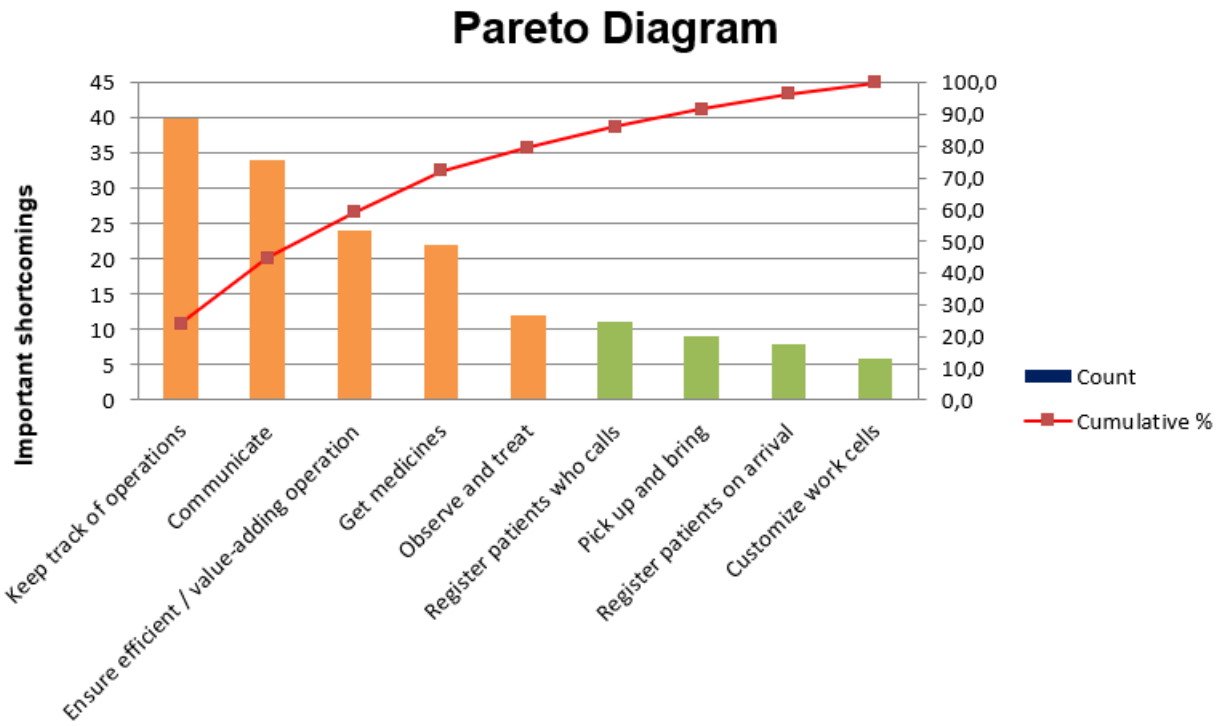


Figure 2 Pareto diagram for prioritizing important deficiencies at the Emergency Care.

**Reviewing**. 5Why and the Pareto analysis support each other, in that both the analytical techniques point to an overview of the emergency room operation as a central main function, in connection with the wishes and need for digitization at Emergency Care. From the 5Why analysis, time pressure emerged as a central root cause, while time pressure is included as a common denominator in all the main functions of the Pareto analysis.

The emergency room should avoid activities where time is spent on unnecessarily tasks, non-value-creating activities, and thus are work activities that do not add any value to the emergency room service (T. Joosten at al. 2009). According to the LEAN principle, it is appropriate for the emergency room service to eliminate non-value creating work activities. We therefore propose to reduce the time spent on the most important deficiencies identified in the Pareto Method Chart, Figure 4.

## *Idea generation phase*

**Find solutions.** We took as a starting point the main functions of the Pareto diagram as well as the core problems that we identified in the 5Why analysis. Then we used questionnaires among stakeholders to conduct a brainstorming process to generate digital problem solutions. From the brainstorming, almost 40 ideas emerged within the overview of operations at Emergency Care, communicating as well as providing efficient / value-creating operations, obtaining medicines, observing and treating as well as ideas to avoid time pressure in the workday. The ideas were then categorized so that moments from all ideas were taken care of and summarized into a complex and complete ideas. The different parts of this idea proposal are presented in the prototype section below.

## *Prototype Phase*

During the definition phase, we uncovered the most important main functions in connection with the wishes and needs for digitization at the Emergency Care. The main functions marked with orange columns in the Pareto diagram (Figure 4) account for 80% of the challenges, and according to (B. Nyen and M. Brudvik 2010) priority should be given to those challenges when improvement work is to be carried out. On this basis, we have assessed solutions that emerged from the idea generation

phase, and developed prototypes that meet the wishes and needs of the employees for digitization at Emergency Care. The prototypes prepared are briefly described below.

**Prototype A - combination machine.** Both before and after the patient's consultation, the staff at the Emergency Care performs some routine tasks, which many patients are able to do on their own, via a self-service automaton. This self-service machine we call a combination machine.

The combination machine is placed centrally in the patient waiting room between the entrance and the reception at the Emergency Care. The multilingual combination-machine allows self-registration, simple self-evaluation, payment and delivery of medicines and numbered RFID bracelets. The RFID bracelet will help with easy identification during the emergency room visit. Those patients who choose to use this combination machine will, among other things, be able to report their arrival and receive information about estimated queue time without having to visit the reception. A queue-overview board is placed in the waiting room. This also corresponds to the numbering on the RFID arm bracelet. Urgent patients will be revealed with the help of self-evaluation that includes checking questions and pain scale as well as the possibility of measuring blood pressure, heart rate, weight, SpO2 and temperature. Furthermore, the patients can pay the bill via the combination machine, and can receive pre-dispensed prescribed medication after the end of the emergency room treatment as they return the RFID bracelet.

**Prototype B - patient recognition.** For rapid and secure identification of patients who are on Emergency Care, a patient recognition system is advantageous. Such a patient recognition system can be especially useful when used in combination with other digital solutions at the Emergency Care. For example, the patient's journal is automatically opened by scanning the patient's identification. Likewise, sample reports or diagnostic analyzes can be automatically assigned to patients by pairing patients with the digital instrument prior to the examination.

Such automatic patient recognition may, for example, be based on face recognition, fingerprint recognition, iris recognition, and voice recognition or by providing patients with an RFID wristband.

**Prototype C - medicine robot.** When Emergency Care was established, it was considered to install an automated medicine room. Unfortunately, due to a lack of adaptability, the solution was considered not appropriate for the patient base of the Emergency Care. Since that time, the Emergency Care has incorporated several municipal emergency services, while the range of automated medical rooms in the market has become much larger. For the employees at the Emergency Care, an automated medicine room will help reduce time spent on stacking, picking and checking medications as well as keeping track of expiration dates and inventory status. In addition, the need for cleaning and washing is greatly reduced. At the same time, the risk of human error is reduced.

Automated medicine rooms are often robotic storage rooms where the capacity of the storage room can be utilized very well. Furthermore, medications are automatically dispensed from the patient record according to doctors' prescriptions as well as generating order lists for complementation of used medicines and medicines that will soon expire. Similarly, these machines have software that adjusts the stock status according to holidays, holidays and seasonally changing needs of, among other things, allergy medicines and flu vaccines.

The automated medicine room can deliver medicines directly to patients via the combination machine or to employees via dispensing machines in the control room. Since there is a requirement for manual signing of Type-A preparations in the medical protocol, such drugs cannot be dispensed via the combination machine. Transport of medicine from the medicine room to the dispensing machines can take place, for example by tube transport, or by placing the dispensing machines side by side with the medicine room.

**Prototype D - Automated login for employees**. In order to carry out their work, the employees at the Emergency Care must use a variety of digital instruments. Figure 5 shows what digital equipment the nurse must verify against during contact with a patient. Likewise, Figure 6 shows what digital equipment the nurses located at the central desk must verify against, in order to perform their work. We measured that it takes 30 minutes at the start of the day for a nurse to log on to the required digital tools.

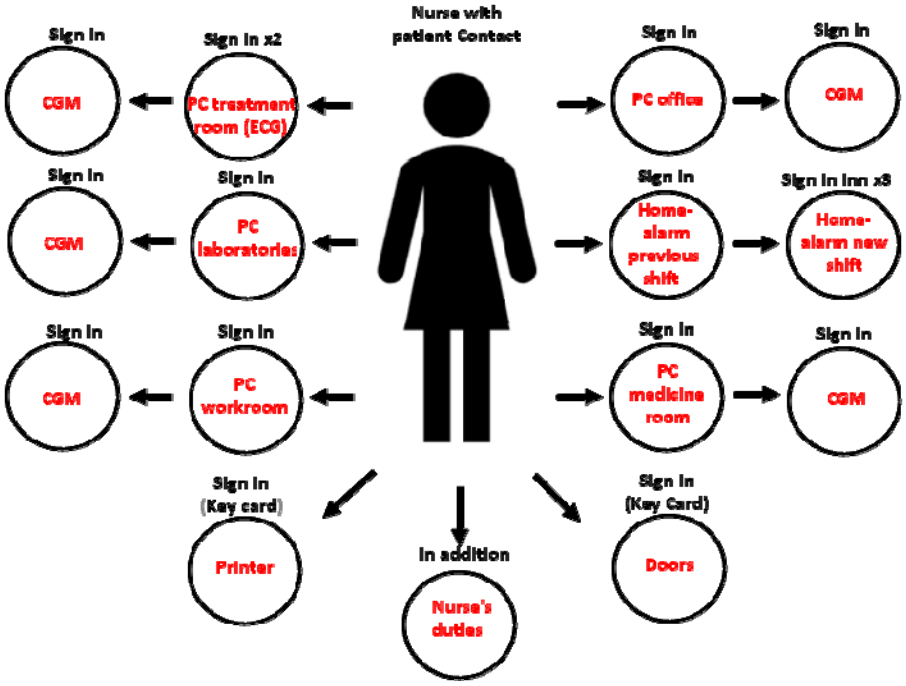


Figure 3 Digital tools that must identify the nurses with patient contact, *as is*.

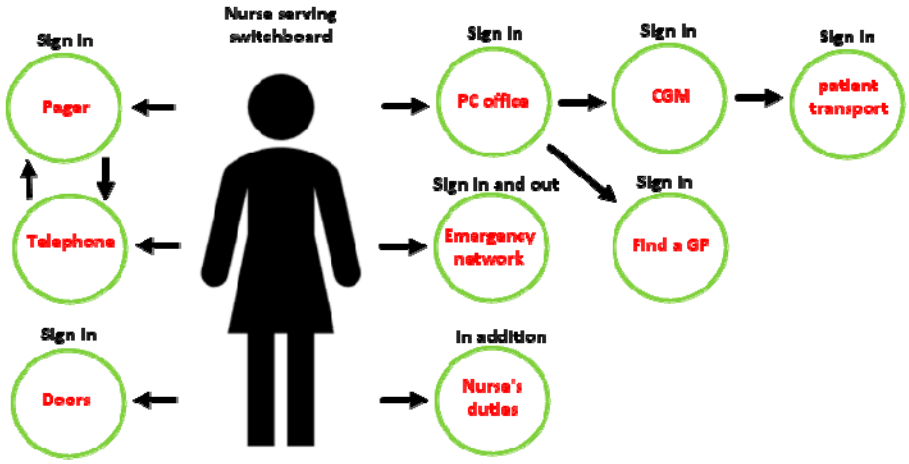


Figure 4 Digital tools that must identify the nurses serving the switchboard, *as is*.

In order to make the working day for the employees at Emergency Care easier, a system for automated login for employees can be established. This automated login system must have a high degree of security, and should therefore not be based on something that can be stolen or easily copied. For example, face recognition will be possible to implement, so that the desired login is done automatically when digital equipment is used.

**Prototype E - Automatic patient journal.** The Emergency Care uses many different digital instruments. When vital measurements and tests are to be taken or diagnosed, the staff must manually enter the results in the patient record, see Figure 7. This requires a lot of time and resources, while the doctors often have to wait for the journal update to be performed manually by a nurse. Manual entry

of the results of vital measurements or diagnoses cannot be performed until the sampling instruments are completed. The processing time of the sampling instruments is often much longer than the time the instrument is operated by the employee. Because of this, the instrument operator often does not get updated the journals once the manual operation of the instruments has ended. Therefore, the employee must either wait for the test results to be processed, or come back at a later time to manually enter the test results into the patient's journal.

The technical solution for the *Prototype E - Automatic patient journal* uses the Internet of Things by sensors on the digital instruments and communicates wirelessly directly with the Patient Journal. The activation of the transmission of medical reports directly into the patient record varies from instrument to instrument. For the instruments that present the test results in real time, it is the operator who activates the report transfer, while the transfer is automatically initiated as soon as process data is generated from instruments with longer processing time.

It is to be noted that in order to optimize the utilization of the prototype for automatic updating of patient records, the system should also be prepared for automatic patient recognition, as described in the section "Prototype: Patient Recognition".

We have prepared a prototype proposal in which the results of tests, diagnostics and examinations as described in the section "Digital work tools at Emergency Care" are transferred directly to the patient's journal, see Figure 8.

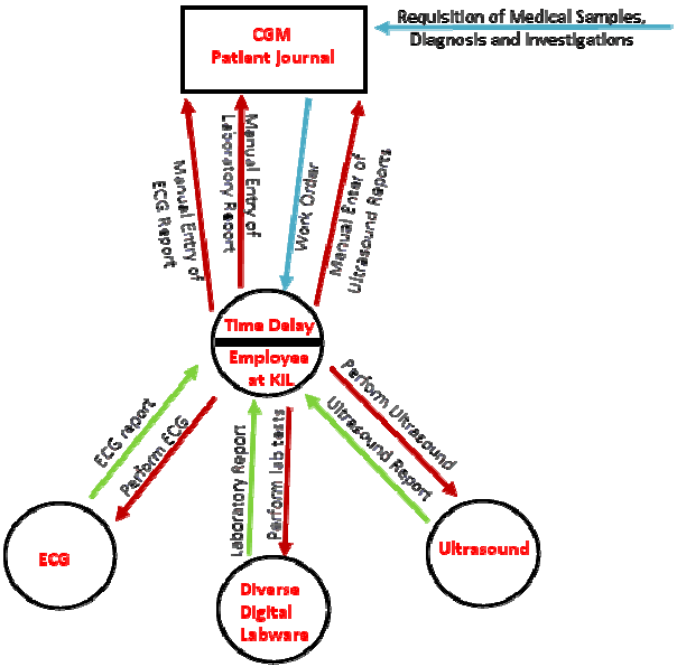


Figure 5 As is situation, Patient Journal update

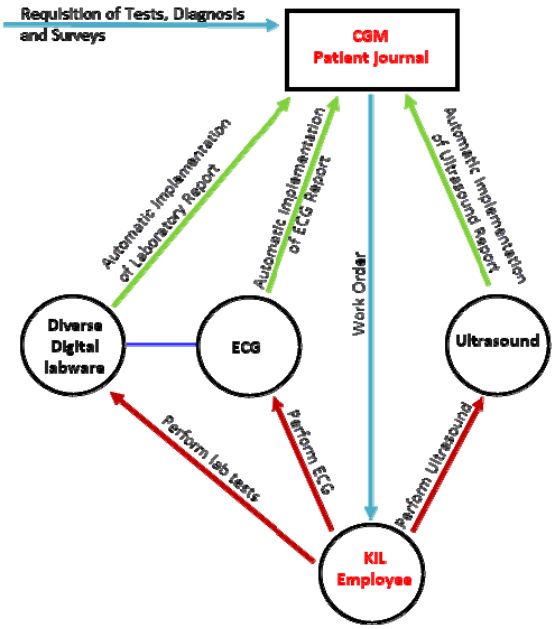


Figure 6 To be situation for patient solution, journal update

**Prototype F - Digital overview screen.** To quickly get an overview of the patient status and work tasks, you can use an overview screen, see Figure 9. This overview screen presents real-time information, and is easily visible to the Emergency Care staff in the control room. The over-view screen has touch screen functionality. On this close-up screen you can tap on the various cells and icons for extended and more detailed information. The screen contains columns where the most important parameters appear, and rows where the different patients with associated parameters are presented. The touch screen also provides data transfer to the patient record for selected parameters.

Through an application adapted to a mobile phone, employees can receive corresponding overview information and perform similar reporting as via the screen.

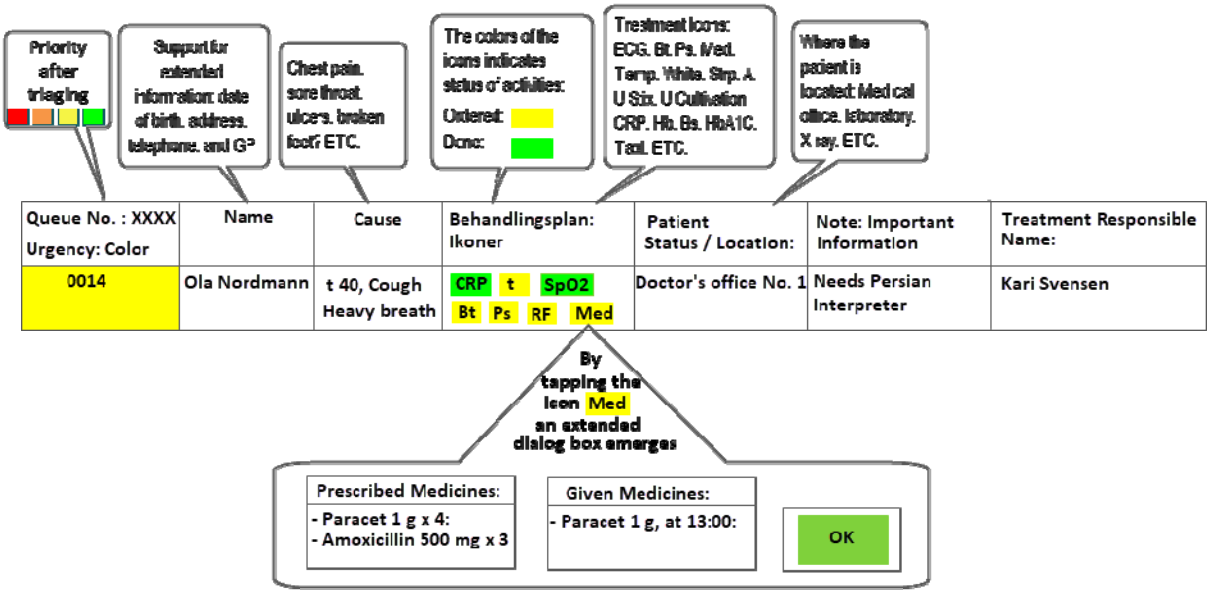


Figure 7 Overview screen of patient status and work tasks

## *Test Phase*

**Testing.** The prototype to be tested consists of many independent individual parts that support each other in a composite prototype proposal. Since the different parts of the prototype proposal are dependent on each other, we have chosen to test the composite prototype proposal together by using a questionnaire based on Likert scale. We also used a free-text questionnaire in which respondents described what they thought was good and what they thought was bad about the different parts of the prototype proposal. In this way, we wanted to capture whether there are parts of the prototype proposal that should be reassessed and what the respondents are reacting to. In Table 4, we present the results of the Likert-Scale survey, where we have used NPS (Net Promoter Score) to analyze the scaling results. Four Emergency Care employees participated in testing the prototype proposal. According to (Reichheld, 2003), those who "strongly agree" will most likely promote our proposal, while those who "agree" will be neutral, while all other responses will be represented by people who are likely to appeal for a new solution. NPS value above zero is considered positive.

The various parts of the prototype proposal were made to fulfill the employees' desired improvements, which emerged from the Pareto diagram in Figure 4. Likewise, the Likert scale has based all of its questions on the same desired improvements. In this way, we have tested all the main functions that the employees have presented as the most important parameters, in order to obtain the best possible value for the employees.

The results from the Likert scale indicate that the respondents were very satisfied with the proposed prototype proposal, but that some parts of the solution proposal did not receive maximum score. In the free-text questionnaire, respondents gave reasons for their views.

From the free-text responses, we have received many positive reasons, such as increased security, improved service, increased patient safety, improved communication, motivation and well-being at Emergency Care. We also received a concern related to the self-evaluation part of the combination machine. One respondent emphasized that patients with intoxicants, psychiatric or geriatric challenges could experience such a self-evaluation component as challenging.

We consider the critical feedback regarding the self-evaluation part of the combination machine to be a useful input. Based on the concerns raised about the combination machine, we have decided to change the use of the self-evaluation part. After an assessment, we have decided that the self-evaluation part should only be used by the patients who want this extra functionality, but that the answers do not form the basis for priority queuing. We therefore propose that all patients should consult a receptionist for triage of health professionals.

Table 4. Likert scale, employee benefits

| SD = Strongly disagree, D = Disagree, N = Neutral, A = Agree, SE = Strongly agree and NPS = Net Promoter Score | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| # | Description | SD | D | N | A | SA | | NPS |
| 1 | The solution proposal can provide better, faster and more transparent digital communication between nurse and doctor | | | | | 4 | | 4 |
| 2 | The solution proposal can provide better, faster and more transparent digital communication between nurse and patient | | | | | 4 | | 4 |
| 3 | The solution proposal can provide a better system and over-view of work tasks at ER* | | | | | 4 | | 4 |
| 4 | The solution proposal can provide safer and faster medication management | | | | | 4 | | 4 |
| 5 | Eliminating many logins in the various systems eliminates unnecessary time spent | | | | | 4 | | 4 |
| 6 | The solution proposal provides faster reporting of the patient's status, condition, tests, treatment and further progress | | | | 1 | 3 | | 3 |
| 7 | The solution proposal can be a good tool for patient manage-ment | | | | 1 | 3 | | 3 |
| 8 | The solution may improve patient flow | | | | 1 | 3 | | 3 |
| 9 | The solution proposal will provide an easier working day | | | | | 4 | | 4 |
| 10 | The solution proposal can streamline and free up time for the employees at ER* | | | | | 4 | | 4 |
| 11 | The solution proposal can provide a more interesting working day | | | | 1 | 3 | | 3 |
| 12 | Do you want such a solution for ER* | | | | | 4 | | 4 |

*ER - emergency room

## Discussion

This study has looked at how methods in Design Thinking and Systems Engineering can be used to map human needs and improve the digitization at the Emergency Care in a small town in Norway. Figure 8 shows what we did in the different phases of the study, and is our proposal for a procedure when systems engineers should use the Design Thinking tool in Systems Engineering. This approach is based on our experience of using the Design Thinking tools, and is a method that we believe has given us well-founded results.

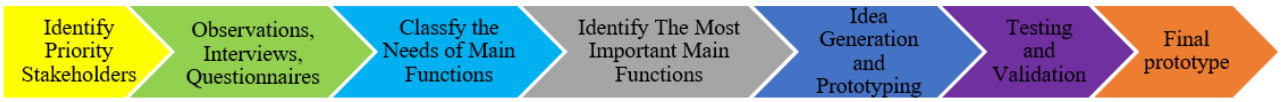


Figure 8. Recommended procedure for implementing digitization tools on Emergency Care.

**Context.** There is a great deal of research on patients' well-being in health care, while the human needs of employees often do not receive the same attention. In this research, the employees were the

main stakeholder. We observed that the nurses often put the patient's needs ahead of their own needs. Furthermore, the employees often have financial concerns related to new solutions.

**Understanding.** The primary researcher has over 10 years of experience as a nurse at a hospital, and is also about to finalize her master's degree in Systems engineering. She has worked for the last year as a call substitute at the Emergency Care. With this in mind, the researcher had a personal understanding of the empathy phase before the start of this study. In addition, through her professional training as a nurse, the researcher had acquired an understanding of the terminology used at the Emergency Care, and was thus able to quickly relate to what was told and observed.

**Observations**. Direct observations of employees were important in understanding their work situation. We used these observations**,** combined with deep insight into the domain, to elicit needs and prioritize. An alternative way of eliciting stakeholder needs could have been to conduct interviews. Such text tools will not give the same richness in information as the direct observation and empathic understanding.

**Self-realization.** The staff had not realized how cumbersome and complicated the current digital solutions were. They told this to the researcher several times. This self-perception of the employees helps to create an understanding of the need for new digitization. The established mutual understanding between the systems engineer and the employees facilitates continued good systems adaptation and systems development after the system has been put into operation. We propose this approach instead of having to spend resources on adapting an unsuitable system that has been developed using a traditional health development project.

**Define using Systems Engineering Tools.** The interview technique 5Why turned out to be very formal with fixed frameworks, while the free in-depth interviews became more informal and creative. The 5Why interview technique is best suited for root cause analysis, while the free in-depth interviews are suitable for acquiring an empathic understanding of the problem that is to be considered.

In the project process, we experienced that it was challenging to apply 5Why interview technique for identifying the human factors at the core of the employees' needs. The nurses who participated in the 5Why strived to put themselves into focus, which meant that professionally sound services for the patients became leading and the focus on their own needs was ignored. Nurses' perception of their own role has historically strong links to altruism, and is something that even today must be aware of interview situations with today's nurses. This is supported by (N. J. Kristoffersen et al. 2011) in the basic nursing textbook that states that educating oneself in nursing involves taking on a basic social responsibility, and that one commits to some important moral values and ideals. Values such as charity and compassion are fundamental to the practice of nursing.

**Ideas, prototype and test**. This study comes out with forty ideas, and these were developed into six different concepts. All of which are technically feasible. We prepared the prototype proposals for improved digitization at Emergency Care. The employees were active contributors and involved in the entire course of the study. The staff evaluated and conducted the testing of the different parts of the prototype proposals. The systems engineer has been able to develop innovative prototype proposals rooted in employees' needs. Thus, the final prototype proposal already had a technological and organizational foundation. In addition, the systems developer has continuously received guiding impulses from the employees, so that unnecessary product development was avoided.

**Challenges**. The researcher interviewed the health personnel and asked for both negative and positive criticism. In spite of this, several of the health personnel preferred to tell stories outside the scope of the. Several of the health personnel were more eager to inform the researcher about their problems than to comment on the proposed ideas.

At Emergency Care, it is usually very hectic. There were no time for in-person interviews nor work groups during the working hours of the employees. Since this study did not have a budget for employee time, we had to conduct 5Why and prototype testing by seeking out Emergency Care employees at home or inviting Emergency Care employees home. The health workers are busy, and need dedicated time to participate in implementation of digital technology. This can allow for undisturbed dialogue and collaboration. In addition to the dialogue with individual employees, a working group consisting of the various disciplines involved should be put together. In this way, follow-up will be ensured throughout the project phase.

### *Further Research.*

**Visual communication.** Professional training, professional language and technical understanding are often different between hospital employees and the systems engineer, which can cause communication challenges. It is therefore important that the system engineer is careful in his communication with the employees. Our experience is that the use of plans, figures and figurative sketches of principle can help to form a common platform as a discussion platform. In this way, one can achieve mutual and fruitful cooperation. This require further research.

**Economic aspects.** This study does not specifically investigate capital expenses and other financial aspects related to digitization at the Emergency Care. Yet, effective digitization has great potentials for a positive impact for staff and patients, while at the same time reducing operating expenses. This is underpinned by the innovation project SamKAD at the Aker Health Arena (Ausen et al. 2017). The economic aspects should be an integrated part of a project realization.

**Patients**. A commercial implementation of digitized soludions should have a holistic picture on stakeholder needs. This certainly includes patients. For our specific case we have patients as a secondary stakeholder, but in fact, we should have included how patients will be affected by the proposed digitization proposals and whether adjustments must be made to comply with the Privacy Regulation.

The initial premise of the paper associated with “staff centric” design approach is incomplete in the bigger context of the soci-economic requirement and impact of health systems. As further work we recommend the inclusion of a wider stakeholder survey (perhaps including patients, patients’ relatives (different perspective), ambulance/paramedical workers) and to look at other constraints (such as cost/affordability, facility constraints such as space/power/environmental factors). It would also have been useful to explore a full lifecycle of treatment from first patient contact (could be on the telephone) to treatment completion and what elements are performed within and without the emergency care facility.

**Engineering, Implementation and Operation.** This research have prototype testing as the final step. Next steps includes Engineering, Implementation and Operation within the health care system.

## Conclusion

The Design Thinking framework facilitates the use of Systems Engineering tools, such as Pareto diagram, Contex diagram and 5Why. By using Systems Engineering tools in the Design Thinking framework, together with the employees, we have come up with a prototype proposal consisting of several subsystems. When these subsystems were tested by the employees, it turned out that the employees were very positive, and at the same time they gave feedback on sub-solutions that they wanted to better investigate. In this way, the employees have been able to participate in system development until a final prototype concept is available.

A central and important part of Design Thinking is the project start-up with its empathy phase This will result in a higher degree of successful use of the final solution, and thus also reduce the risk of

waste by implementing unsuitable systems. The methodology can help the health workers to gain a deeper understanding of the scope of their own work. This is after the systems engineers have summarized, visualized and presented their understanding of the issues facing the employees. The established mutual understanding between the systems engineer and the employees facilitates continued good systems adaptation and systems development after the system has been put into operation. We propose this approach instead of having to spend resources on adapting an unsuitable system that has been developed using a traditional health development project.

## References


Agency for Healthcare Research & Quality 2018, *Six Domains of Health Care Quality*, Rockville.

Arthur, J. (2012). *Research Methods & Methodologies in Education*, SAGE, London, UK.

Ausen, D et al. 2017, Development and implementation of digital collaboration and support on CAD, A regional research and innovation project (in Norwegian: Utvikling og implementering av digital samhandling og oppgavestøtte på KAD, Et regionalt forsknings- og innovasjonsprosjekt), Sintef Digital Report, Oslo, Norway.

Chimi, C. J., & Russell, D. L. (2009, November). The Likert scale: A proposal for improvement using quasi-continuous variables. In *Information Systems Education Conference, Washington, DC* (pp. 1-10).

Direktoratet for økonomistyring (2015). The guide to root cause analysis (In Norwegian: Veilederen til rotårsaksanalyse), Oslo, Norway.

Plattner, H., Meinel, C., & Weinberg, U. (2009). *Design-thinking*. Landsberg am Lech: Mi-Fachverlag.

Gitmark, H. (2017). The robots are coming - what does the public sector respond (In Norwegian: Robotene kommer - hva svarer offentlig sektor), Agenda, Oslo, Norway.

Helsetilsynet (1998). Quality managed health organizations - for you as an employee (In Norwegian: Kvalitetsstyrte helseorganisasjoner – til deg som medarbeider), The State Health Inspection Series

(Statens helsetilsyn utredningsserie), Oslo, Norway.

Joosten, T., I. Bongers and R. Janssen (2009). Application of lean thinking to health care: issues and observations. *International Journal for Quality in Health Care.*

Jære, L. (2017). Saving millions with nurses and doctors as IT clients, (In Norwegian: Millionbesparelser med sykepleiere og leger som it-bestillere), *Gemini*, Trondheim

Langnes, R. (2018). Nurses must learn to say no, (In Norwegian: Sykepleiere må lære seg å si nei), *Sykepleien*, Oslo, Norway.

Lovdata (2015). Regulations on requirements and organization of municipal emergency room, ambulance service, emergency medical service (In Norwegian: Forskrift om krav til og organisering av kommunal legevaktordning, ambulansetjeneste, medisinsk nødmeldetjeneste mv). The Norwegian emergency medicine regulation (Akuttmedisinforskriften).

Maher, L. (2007). A Guide to Retaining Practice: Guidance and Measurement Tools (In Danish: En guide til fastholdelse af praksis: Vejledning og måleredskab), Center for Kvalitetsudvikling, Region Midtjylland, Denmark.

Nyen, B. (2010). Paretoanalyse, Helsebiblioteket, Oslo, Norway.

Pinto, J., Falk, K., & Kjørstad, M. (2019, July). Inclusion of human values in the specification of systems: bridging design and systems engineering. In *INCOSE International Symposium* (Vol. 29, No. 1, pp. 284-300).

Rasmussen, I. (2004). Development of methodology for assessment of baseline, Report Prepared for Enova SF (IN Norwegian: Utvikling av metodikk for vurdering av baseline, Rapport Utarbeidet for Enova SF), Vista Analyse, Norway.

Reid, P. P., Compton, W. D., Grossman, J. H., & Fanjiang, G. (2005). The Tools of Systems Engineering. In *Building a Better Delivery System: A New Engineering/Health Care Partnership*. National Academies Press (US).

Roberts, J. P., Fisher, T. R., Trowbridge, M. J., & Bent, C. (2016, March). A design thinking framework for healthcare management and innovation. In *Healthcare* (Vol. 4, No. 1, pp. 11-14). Elsevier.

Seehusen, J. (2019). Digitization of the Health Service. Doctors and nurses use many computer systems. Yet the health care system is drowning in paper (In Norewgian: Digitalisering av Helsevesenet. Leger og sykepleiere bruker mange datasystemer. Likevel drukner helsevesenet i papir), *Teknisk Ukeblad*, Oslo, Norway.

Seidman, I. (2006). *Interviewing as qualitative research: A guide for researchers in education and the social sciences*. Teachers college press, US.

Serrat, O. (2017). *The Five Whys Technique, Knowledge Solutions*, Springer, Singapore

Sols, A. (2014). *Systems Engineering: Theory and Practice*, Universidad Pontifica Comillas, Madrid, Spain.

## Biography

**Jurate Schønning**. Jurate holds a bachelor's degree in nursing, followed by more than 10 years of work experience in the health sector, including intensive care units and emergency care units. In addition, she holds a bachelor's degree as a mechanical engineer and is now in the final phase of a master's degree in systems engineering with industrial economics.

**Kristin Falk**. Professor Kristin Falk has lead technology teams in start-ups, SME and large corporations, primarily in the energy industry. She has been in the industry for more than twenty years. She is teaching Systems Engineering at the University of South-Eastern Norway. Her research focus is 'how to create systems fit for purpose in a volatile, uncertain, complex, and ambiguous world'.