BSc Thesis Industrial Engineering and Management

# ASSESSING THE CAPACITY PERFORMANCE OF VIRTUAL CARE PATHWAYS: A CASE STUDY OF STROKE PATIENTS IN ISALA HOSPITAL

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Bachelor thesis: assessing the capacity performance of virtual care pathways: a case study of stroke patients in Isala Hospital

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# Management Summary

**Introduction**

Due to increasing numbers of patients hospitals are faced with the need to explore alternative treatment paths that allow treating larger patient volumes with the existing amount of resources. This research, therefore, aims to gain comprehensive information and insights regarding the performance of virtual care, specifically in terms of capacity and costs. To this end, we conduct a case study at the Isala Hospital in Zwolle, the Netherlands, on cerebrovascular accident (CVA) patients during their rehabilitation phase. We compare the capacity performance of the CVA rehabilitation pathway before (conventional pathway) and after the transformation into a virtual pathway. We define the following main research question: **What is the impact of a virtual rehabilitation pathway from a capacity management perspective?** We initiate our research by conducting a systematic literature review on capacity assessment in hospitals with a specific emphasis on telemedicine. Subsequently, we define a list of key performance indicators (KPIs) based on the literature to assess the capacity performance of a pathway and define our research methods. It follows a context analysis of the two pathways and a descriptive and diagnostic data analysis assessing six experiments based on two samples of patients. The first data sample, which we refer to as the *control group* was collected in 2019, before the implementation of the virtual pathway, and contains 238 patients. The second data sample, which we refer to as the e-coach group, was collected in 2022/2023, after the implementation of the virtual pathway and includes 163 patients. These analyses serve as the foundation for the derivation of the conclusions.

**Capacity in Healthcare**

During our systematic literature review, we found that the majority of articles assessing hospital capacity relied on KPIs that use numbers related to beds as a primary metric to evaluate performance. However, this gives rise to several challenges, one of which is the difficulty of assessing the capacity of virtual care by simply measuring the number of beds. Furthermore, we discovered that virtual care can save costs for all stakeholders (Peters et al., 2022) and lead to 26% shorter appointments than in-person appointments (Tan et al., 2020). Moreover, virtual care is more suitable for follow-up appointments of controlled patients than for treating uncontrolled patients (Yu & Bayram, 2021). Ultimately, to the best of our knowledge, there is no research assessing the effect of virtual pathways on the capacity performance of the hospital using a range of capacity KPIs.

**Results**

Derived from several research articles and the constraints of our case study we determined a list of KPIs for our data analysis containing, *the number of appointments per patient* and *by appointment type*, *the total appointment length per patient, the total working time of healthcare professionals per patient* and *the total treatment costs per patient*. Assessing the context, our findings revealed the following primary distinguishing factors between the virtual pathway and the conventional pathway. The conventional pathway includes two outpatient visits (hospital visits without staying overnight) with the specialized nurse, whereas the virtual pathway only includes one optional outpatient visit at the end of the rehabilitation and three planned telephonic consultations. In addition to that, the virtual pathway offers the opportunity to incorporate the use of an e-coach (mobile application). The e-coach is monitored by nurses of the hospital that conduct follow-up consultations in case patients indicate symptoms of a certain condition.

The data analysis shows that patients in the e-coach sample had 4.5 times more appointments per patient compared to the control group and a shorter average appointment duration of 16 minutes

compared to 22 minutes. When examining a breakdown of the appointment time it became evident that the number of outpatient visits per patient is about the same (0.4) for both sample groups and that the high number of appointments of the e-coach sample patients is mainly caused by unplanned telephonic consultation that make up approximately 50% of all appointments. Investigating the average total appointment duration we showed that the total working time of healthcare professionals for patients of the e-coach group is, in all experiments, larger than for patients of the sample group and that the total appointment time is at least twice as high for e-coach sample patients (67 min, 30 min). Lastly, we conducted a cost analysis measuring the total treatment costs per patient. In all experiments, costs range between 171€ and 210€. The virtual pathway approximately breaks even in costs with the conventional pathway in experiments 4 and 5. Experiment 4 assumes that administrative appointments that currently exist due to set-up activities of the e-coach and one planned telephonic consultation are removed and the number of outpatient visits is reduced to 0.5 per patient. Experiment 5 supposes that administrative appointments and one planned telephonic consultation are removed, and unplanned telephonic consultations are reduced by 80% to 7 minutes per patient. In these experiments, the virtual pathway and the conventional pathway would have average treatment costs per patient of approximately 172€. Overall, reducing the number of outpatient visits seems more reasonable, as these appointments cause the highest costs.

**Conclusion**

We conclude that the virtual pathway for CVA patients in Isala in its current state has a negative impact on the capacity performance of the hospital, due to a greater number of appointments, longer treatment times, and higher costs. Nevertheless, when adjusted and even further conducted virtually, it has the capability to become more cost-efficient. Moreover, since patients have more contact moments with healthcare professionals in the virtual pathway, it could outperform the conventional pathway in terms of quality of care.

This research could be extended and continued by gathering larger samples and more accurate data about appointments and costs. Moreover, other patient types could be taken into account and a more detailed cost scheme applied, as well as a wider range of KPIs assessed.

We recommend Isala to keep the virtual care pathway and continue improving its performance by replacing outpatient visits with telephonic consultations. Furthermore, we believe this research provides valuable support to hospitals in the implementation of virtual care pathways by emphasizing the importance of reducing outpatient visits and contributing to a better healthcare system and scientific research within healthcare.

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## List of Abbreviations

| | |
|---|---|
| **ADM:** | Administrative |
| **CVA:** | Cerebrovascular accident |
| **KPI:** | Key performance indicator |
| **TC:** | Telephonic consultation |
| **TCVK/TCVPK:** | Telephonic consultation with a specialized nurse |
| **TCWK6:** | Telephonic consultation week 6 |
| **TCWK10:** | Telephonic consultation week 10 |
| **VCC:** | Virtual care center |

# 1. Introduction

Hospitals will face increasing numbers of patients in the upcoming years (Oksuzyan et al., 2020). While pandemics like Covid-19 can result in a surge of patients, the ageing populations in many Western countries also contribute to increased demand for healthcare services (*Public Health and Care*, 2020; Office for National Statistics, 2022). Only based on demographics, the absolute number of coronary heart diseases in the Netherlands is expected to increase by 43% from 2018 to 2040 (*Public Health and Care*, 2022). To cope with the increasing numbers of patients, hospitals need to develop alternative treatment methods that demand fewer resources. One measure is to adjust care pathways and create alternative care pathways. A care pathway is "a methodology for the mutual decision-making and organization of care for a well-defined group of patients during a well-defined period of time" (Van Dam et al., 2013).

During the recent Covid-19 pandemic, social distancing was one of the crucial measures to stop the spread of the virus. Therefore, many hospitals started introducing telemedical (also sometimes referred to as digital health, virtual care or remote healthcare) projects such as telerehabilitation, which "encompasses a range of rehabilitation and habilitation services that include evaluation, assessment, monitoring, prevention, intervention, supervision, education, consultation and coaching" (Richmond et al., 2017).

Telemedicine refers to "the use of electronic information and communications technologies (ICT) to provide and support healthcare over a distance" (Tan et al., 2020). Even though telemedicine is not a new concept and was used in simple forms ever since the 1900s, it had its breakthrough with the extended use of the internet and then recently with the Covid-19 pandemic, as anti-infection measures required healthcare appointments without any physical encounters (*Nasdaq*, 2023) (Union European, 2018). As the mass implementation of telemedical or digital health services has been very recent, research on telemedicine is still limited. The following paragraphs give an overview of the current state of literature revolving around the field of telemedicine and virtual care pathways.

As of now, the use of digital health strategies generally has positive and negative impacts on the quality of care of equal magnitude. This was shown by Silva et al. (2022), who conducted a scoping review to map the use of digital health strategies worldwide. Among other things, they concluded that the use of information and communication technology should be expanded.

On one hand, Zhang et al. (2022) showed that telemedicine decreases the inequality of medical resources between rural and urban areas and solves information imbalances with the effect of immediate sharing of information. Additionally, telemedicine has been found to enhance healthcare accessibility and mitigate the risks of infection (Mahmoud et al., 2022).

Pimenta et al. (2023) examined the use of digital health within a pulmonary rehabilitation program irrespective of the pandemic. Pulmonary rehabilitation programs help people with chronic respiratory diseases to improve the function of the lungs. They discovered that digital health is a promising solution for pulmonary rehabilitation as it overcomes some of the major barriers of that field such as accessibility issues, and helps to maintain the positive results through physical activity tele-coaching.

On the other hand, telemedicine also has its downsides and limitations. Many studies mention concerns about data privacy, the limitations of virtual appointments and the risks to the patient-physician relationship (Zhang et al., 2022). In that sense, telemedicine is not suitable for all medical conditions and is not an appropriate model when it does not allow doctors to meet established

medical standards (Zhang et al., 2022). Moreover, there remains insufficient evidence regarding the treatment effectiveness of telemedicine. It is also noteworthy that telemedicine still encounters challenges such as relatively low acceptability among patients and healthcare professionals. Concerns surrounding costs and disparities in internet access and availability of technological devices further contribute to the existing limitations (Pimenta et al., 2023). According to Mahmoud et al. (2022), infrastructure and regulatory barriers are still the greatest obstacles to broader use (Mahmoud et al., 2022).

In conclusion, former research has shown that digital health strategies improve access (Mahmoud et al., 2022), decrease imbalances of medical resources (Zhang et al., 2022) and improve the quality of care (Pimenta et al., 2023), but are not suitable for all medical conditions (Zhang et al., 2022) and still face acceptability and regulatory barriers (Mahmoud et al., 2022).

While there is considerable research evaluating the impact of telemedicine on the quality of care and its social impacts, there remains a significant dearth of research examining its effects on logistics. To the best of our knowledge, there are only a few that assess a restricted range of factors regarding the impact of virtual care pathways on capacity, as stated in the problem cluster in Appendix 1.1. We discuss these articles in Chapter 2 of this report.

Hence, the objective of this research is to gain more information about the performance of virtual care in terms of capacity and costs in order to reduce current barriers and possibly promote the implementation of telemedicine, based on evidence. This research project looks at one specific case of cerebrovascular accident (CVA) patients at Isala Hospital in Zwolle, the Netherlands. Studying this case allows us to derive information about the impact of virtual care pathways that is also relevant for other hospitals and similar units and projects.

Isala is a Dutch hospital organization with five locations in Zwolle, Meppel, Steenwijk, Kampen and Heerde. Currently, around 7000 employees work at Isala to provide top general care and highly specialized care in all kinds of fields, from antenatal diagnostics to stem cell and bone marrow transplantation (*Isala*, n.d.). The Isala Hospital in Zwolle set up a Virtual Care Center (VCC) in 2020, that allows treating patients using virtual care pathways. The VCC is currently funded by a transition fund from the government which allows hospitals to research the transition of healthcare.

Various virtual care pathways for different types of patients have been implemented so far. They provide the option for patients to receive remote monitoring at home by nurses from the VCC or to receive care at home from mobile nurse teams. One of the projects of the VCC is the virtual care pathway for CVA patients (patients that experienced a stroke). These patients used to be sent home during the rehabilitation phase and had two outpatient visits at the hospital during their rehabilitation phase of twelve weeks. In 2020, the VCC established a pathway wherein CVA patients are monitored and cared for at home during their rehabilitation phase through the utilization of an e-coach, which takes the form of a mobile application (app). This app not only offers information about the rehabilitation process but also periodically prompts the patient with questions to assess their condition and monitor their progress. Thus, patients receive a higher quality of care and are less required to come to the hospital for outpatient visits. In the following parts of this report, we refer to the pathway that was used before the introduction of the VCC and included several outpatient visits as *conventional pathway* and to the pathway that included the use of an e-coach as *virtual pathway.*

The research we conduct by comparing the conventional pathway with the virtual pathway at the Isala Hospital in Zwolle, aims to discover important information about an alternative approach for treating CVA patients. The decision to focus on CVA patients was influenced by the fact that CVA patients have a substantial population, making it easier to gather a significant sample size for the analysis. Furthermore, the pathway followed by CVA patients appeared to be well-suited for the implementation of a virtual pathway. The results could lead to decisions on the strategic level of the hospital's resource capacity planning (Hans et al., 2012) and could not only be used by Isala but also by other healthcare organizations.

We follow several steps to answer the sub and thus the main research questions. Our problem-solving approach follows the steps of the managerial problem-solving method (MPSM) which is an established approach for industrial management research projects by Heerkens & van Winden (2021). This section explains the main research question and the according sub-questions. The main research question is "the hypothesis that best states the objective of the research" (Cooper & Schindler, 2014). It guides the research and is answered at the end of the project. For this project, the main research question is as follows.

**What is the impact of a virtual rehabilitation pathway from a capacity management perspective?**

The main research question includes four sub-questions that need to be answered in order to be able to answer the main question.

1. **What is capacity in healthcare and how can it be assessed?**

We answer the first question by conducting a systematic literature review. We investigate how capacity is defined in healthcare literature and how it can be assessed. Based on the literature research we define the KPIs for this research.

2. **How do we analyse the pathways and the data?**

This question gives an overview of the assessment methods used to analyse the pathways and the data sets.

3. **How do the conventional pathway and the virtual pathway perform?**

We answer the third question by presenting the results of the analysis of the pathways and the data.

4. **Which recommendations can be given to the hospital regarding the treatment of CVA patients in terms of capacity management?**

The final question contextualizes the results within the present circumstances and literature, providing recommendations on the appropriate course of action for the hospital.

# 2. Capacity in Healthcare

This section gives an introduction to hospital capacity assessment and reviews the current state of hospital capacity assessment of virtual healthcare based on literature. Afterwards, we determine the KPIs for the data analysis of this research.

## 2.1. Literature Review

Hospital capacity, in general, can be defined as "an upper limit that characterizes the optimal performance of the hospital in terms of productivity, output, or the number of patients treated" (Humphreys et al., 2022). The analysis of hospital capacity is of high importance as many people need to be treated in a short period while expecting a high level of care (Burdett et al., 2017).

### 2.1.1. Capacity Assessment in Hospitals

Hospital capacity assessment has been investigated in many research papers before. Burdett et al. (2017) developed an approach that assesses the theoretical capacity of a whole hospital and also created a linear programming model to help hospitals with capacity planning and resource allocation activities. Also Hu et al. (2021) and Masoompour et al. (2015) analyzed patient capacity in hospitals. All of these researches used KPIs related to the number of beds such as “bed turnover” and “bed occupancy rate” to assess the capacity of a hospital. These kinds of KPIs might have been sufficient for their research projects. However, according to Rechel et al. (2010), several problems can be related to this approach. Firstly, the number of beds does not provide insights into all services available. Secondly, there is a trend towards more outpatient visits and shorter stays of inpatients, which is not considered when looking at the bed capacity. And lastly, the use of the number of beds as the only capacity indicator does not consider the capacity that alternative pathways could provide. Hence, using bed numbers as the only capacity indicator is not always useful. Especially when assessing virtual care pathways it is not applicable as the bed numbers do not restrict the capacity for patients that are not treated at the hospital. To conclude, hospital capacity assessment and planning should not only be based on beds but rather on the ability to deliver processes (Rechel et al., 2010).

### 2.1.2. Capacity Assessment of Telemedicine

Several studies show that virtual care and telehealth reduce costs for healthcare providers (American Hospital Association, 2016) and municipalities (Hakanen et al., 2023). The patient saves expenses on diagnosis, treatment and transportation, while the waiting time is greatly reduced (Zhang et al., 2022). Nevertheless, this depends on the specific type of technology used, the amount of care provided and the scale of the project, as there is a sufficient scale of use needed to save costs (Peters et al., 2022). The results of Yu & Bayram (2021) suggest that virtual care is more suitable for follow-up appointments of controlled patients than for treating uncontrolled patients. They also conclude that virtual appointments are not as effective as office appointments, but are equally important because of lower costs.

Moreover, according to Tan et al. (2020), virtual appointments were found to be, on average, 26% shorter in duration compared to office appointments. This suggests that virtual appointments can be used to increase capacity in primary healthcare settings since more patients can be treated at the same time.

Ultimately, virtual care saves costs for all stakeholders when implemented on a sufficiently large scale and for suitable appointment types (Peters et al., 2022). To our knowledge, there do not exist more extensive papers assessing a wider range of KPIs regarding the effect of telemedicine on the capacity

of hospitals. Therefore, we want to achieve a more holistic picture of the effect of telemedicine on hospital capacity with this research.

## 2.2. Definition of KPIs

In this research, we assess the capacity of the rehabilitation phase of the stroke unit within the neurology department. Hereby, we predominantly look at staff capacity. To compare the conventional care pathway with the virtual care pathway, key performance indicators need to be defined.

We conducted a systematic literature review (Appendix 2.1.) to find KPIs that are commonly used to assess capacity in hospitals. Most KPIs were taken from mathematical models that calculate the capacity of a hospital or serve as demand-planning tools (Bae et al., 2017; Burdett et al., 2017; Cudney et al., 2019). One has to keep in mind that these models were developed to measure capacity in conventional hospitals without considering telemedicine and rather focusing on inpatient capacities. Hence, many KPIs used in the literature do not apply to this research. Table 1 gives an overview of the KPIs that are mentioned in the literature and are theoretically applicable. The table also shows the papers we could find that specific KPI in. The last column shows a rating of each KPI regarding the relevance and applicability of this research. The KPIs that we selected for our data analysis are highlighted in green.

*Table 1: KPI selection based on literature*

| **KPI / Source** | (Peters et al., 2022) | (Zhang et al., 2022) | (Pastora-Bernal et al., 2021) | (Li & Benton, 1996) | Burdett et al., 2017) | (Kokangul et al., 2016) | (Cudney et al., 2019) | (American Hospital Association, n.d.) | (Martinez et al., 2018) | (Almasi et al., 2021), | (Tan et al., 2020) | (Bae et al., 2017) | (Masoom Masoompour et al., 2015) | (Terning et al., 2022) | **Total times mentioned in the** | **Relevance of this research** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1. Costs (in general)** | x | x | x | | | | | | | | | | | | 3 | • Highly applicable<br>• Of high interest for stakeholders<br>• Summarizes several other KPIs |
| **2. Patient costs per day** | | | | x | | | | | | | | | | | 1 | |
| **3. Costs per case** | | | | x | | | | | | | | | | | 1 | |
| **4. Total number of patients treated** | | | | | x | | | | | | | | | | 1 | • Compares treatment capacity<br>• Independent of pathway |
| **5. Number of admissions** | | | | | | x | x | | | | | | | | 2 | • Also dependent on the inpatient treatment phase |
| **6. Number of readmissions** | | | | | | | | x | x | | | | | | 2 | • Is dependent on the quality of the rehabilitation program not on e-coach |
| **7. Number of discharged patients** | | x | | | | | | | x | x | | | | | 3 | • Also dependent on the inpatient treatment phase |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **8. Number of consultations** | | | | | | | | | | x | | | | | 1 | • High applicability |
| **9. Length of stay** | | | | x | | | x | | x | x | x | x | x | x | 8 | • Relevant for all stakeholders<br>• Not fully applicable to virtual pathway |
| **10. Waiting time** | | | | | | | x | | | | | x | | x | 3 | • Not applicable to virtual appointments<br>• insufficient data |
| **11. Treatment time** | | | | | | | | x | | | | | | | 1 | • of high interest for stakeholders<br>• applicable to both pathways |

Based on Table 1 and the requirements of this research we select the following KPIs.

1. **Total number of appointments per patient and appointment type**

This KPI is derived from KPIs 5,6 and 8 which were mentioned several times in the literature. We further differentiate between the types of appointments. This KPI measures the total number of appointments that concern the CVA condition per patient and the type of appointment.

2. **Total appointment duration per patient and appointment type**

This KPI is based on KPIs 9 and 11 that are used in the literature. Even though there is no inpatient stay in virtual care pathways, we assess the total appointment length because it is still relevant to gain insights into the time patients spend in treatments. Next to the number of appointments, this KPI can give more detailed information about the actual time patients obtained services. Ultimately, it measures the total appointment duration of all CVA-related appointments per patient and type of appointment.

3. **Total working time of healthcare professionals per patient and appointment type**

Moreover, we want to observe the effect of the type of pathway used on the total working time per patient. Unlike the total appointment length per patient, this KPI also takes indirect care activities such as administrative and preparational tasks of staff members into account. It has not been used in any literature that we reviewed, however, it is part of the "cost" indicator, as staff costs have a large impact on total treatment costs. Hence, this KPI measures the total working time healthcare professionals spend on CVA-related appointments per patient and type of appointment.

4. **The total treatment costs per patient**

The performance indicator "costs" was used in three research projects. Additionally, "costs per day" and "costs per case" have been shown to be useful KPIs, as they encompass various factors and provide a comprehensive summary of other KPIs. (Li & Benton, 1996). Moreover, they possess substantial applicability and great relevance due to the shared concern of all stakeholders regarding costs. The exact method to compute this KPI is explained in Chapter 3 of this report.

## 2.3. Conclusion

In this chapter, we assessed the literature regarding capacity assessment in hospitals and particularly in telemedicine. There exist several research articles that assess the capacity of a hospital using bed numbers. For our research, these assessment strategies are not suitable as the capacity of virtual care pathways does not depend on the number of beds in a hospital. Hence, we rather need to measure

the ability to deliver processes (Rechel et al., 2010). When investigating telemedicine, we found out that some capacity measures have been investigated before. In several articles, they concluded that the use of telemedicine reduces costs for the hospital and for the patient if applied on a sufficiently great scale (Hakanen et al., 2023; Zhang et al., 2022). Furthermore, telemedicine can increase efficiency (Tan et al., 2020), however, it is not suitable for all types of patients (Yu & Bayram, 2021). Nevertheless, to the best of our knowledge, no research has been conducted that assesses several capacity KPIs in a telemedicine framework. Subsequently, we defined the following KPIs based on a systematic literature review that is applicable to assess the capacity of a virtual care pathway: *number of appointments per patient and appointment type, the total appointment duration and working duration of healthcare professionals per patient and appointment type, and the total treatment costs per patient*.

# 3. Methodology

This Chapter describes the methods used in the analysis of this study. We start explaining the settings and continue with the design of this study. Within the study design section, we particularly focus on data sources, data cleaning and the experiments applied in the analysis.

## 3.1. Study Settings

This section provides an overview of the demographics of CVA patients and our sample groups and thereby gives an overview of the context of this research study.

In 2016, 13.7 million incident strokes occurred worldwide. Around 87% of these strokes were ischemic strokes, where a blood clot blocks an artery leading to the brain (Saini et al., 2021). The general risk of a stroke depends on many factors like lifestyle, genetics, gender and age. Men are 30% more likely to experience a stroke, however, age is the predominant factor affecting the probability of experiencing a stroke. Patients younger than 50 years of age have a 10 times smaller probability of developing a stroke compared to patients above 50 years of age (Pizov & Pizova, 2018). The mean age of developing a stroke incident decreased from 71.2 years in 1993/1994 to 69.2 years in 2005 (Kissela et al., 2012). In Isala, we estimate the number of CVA patients to increase by 5.5% per year in the period from 2019 until 2030, which would lead to approximately 2500 more CVA patients in 2030 compared to 2019.

## 3.2. Study Design

This section explains the methods we use for our analysis to compare the virtual pathway to the conventional pathway. We start explaining the sample selection, continue with the data preparation and the context analysis and end with the data analysis and the experiments.

### 3.2.1. Data Sources and Sample Selection

In this section, we describe the data sources, their properties and explain the choice of data used for our samples.

The data is retrieved from the electronic patient record. It contains data about appointments, the patient's condition and medication. The data is collected and recorded by nurses and doctors to keep track of a patient's medical history and schedule appointments. For this study, we solely examine data about the patients' demographics, appointment history, and appointment type and duration.

The first sample for our case study includes CVA patients that went through home rehabilitation with the support of the e-coach between 01.09.2022 and 09.06.2023. We specifically chose this time period because prior to September a different e-coach was in use. The length of the selected time period was crucial to ensure that we had a sufficiently large patient population for our analysis according to Yamane's formula with a margin of error of below 5%. Related to these patients we have data about 884 appointments of which are 605 telephonic appointments. In the following chapters, we refer to this sample as the *e-coach group*.

The second sample includes CVA patients that went through home rehabilitation between 01.09.2019 and 31.12.2019. The chosen time period is ideal for a comparison with the e-coach sample due to three main reasons. Firstly, during this period, the virtual care pathway had not been implemented yet, providing an opportunity to evaluate the impact of its introduction. Secondly, it predates the Covid-19 pandemic, which ensures that any observed differences in outcomes and experiences are not influenced by the unique circumstances and challenges posed by the pandemic. Moreover, it includes a similar number of patients. This sample consists of 238 patients. In connection with these patients, we received information about 290 appointments, including 32 telephonic appointments. To this sample we refer as *control group*.

Moreover, it is necessary to understand the different types of appointments included in our data analysis in order to be able to interpret the results. The section below describes all types of appointments and their appointment code from the electronic patient record.

*Table 2: Overview of appointment types*

| Nr. | Appointment Name | Appointment code | Description |
|---|---|---|---|
| 1 | Administrative | ADM* | Appointments used for administrative activities without the participation of a patient. Mostly conducted by the specialized nurse to set up and improve the e-coach. |
| 2 | Telephonic consultation | TC | An unscheduled telephonic consultation conducted by the monitoring nurses from the VCC. It is usually a follow-up appointment on feedback given through the e-coach |
| 3 | Telephonic consultation week 6 | TCWK6 | A scheduled telephonic appointment conducted by monitoring nurses from the VCC in week 6 after discharge. Isala already considered the removal of this appointment. |
| 4 | Telephonic consultation week 10 | TCWK10 | A scheduled telephonic appointment conducted by monitoring nurses from the VCC in week 10 after discharge. |
| 5 | Telephonic consultation with a specialized nurse | TCVS, TCVPK | A scheduled telephonic consultation with a specialized nurse that replaces an outpatient visit. |
| 6 | Outpatient visit (with specialized nurse) | CPCVAVS, CPCVAWVS, CPCVAVPK, CPYS, CCVA, CP, NP | A scheduled outpatient visit with a specialized nurse. |

To evaluate the set of KPIs, it is essential to have information regarding treatment and staff expenses. To this end, Isala supplied data concerning the costs associated with each treatment category as well as the staffing costs (Appendix 3.1.). The costs used for the analysis are multiplied by a random factor (in order to comply with the data regulations of Isala) and hence, do not represent reality. Nevertheless, as all numbers are multiplied by the same factor, it does not have an impact on the results of this research.

### 3.2.2. Data Preparation

Since the data in the electronic patient record was collected to keep track of a patient's data, before the analysis, the data from the electronic patient record has to be screened for data inconsistencies and other factors that could become an issue during the analysis.

Looking at the total number of appointments per person we observe that several patients do not have any appointments listed. This could be due to incomplete data sheets or an unusual care pathway. Since these patients would bias the KPIs we disregard them in our calculations.

Moreover, the data extraction software provided all appointments tagged with the specialism *neurology*. These appointments also include some physiology appointments. Since these appointments are not affected by the pathway type, they are disregarded in the analysis. Furthermore, the list of appointments was filtered by the pseudo ID of the patients and the *specialism neurology.* Hence, the list of appointments includes all appointments fitting in these categories, which also includes Parkinson appointments. Since these appointments are not related to the CVA care pathway we also disregard them in our analysis.

### 3.2.3. Context Analysis

The analysis of the context serves multiple purposes. Firstly, it aims to enhance understanding of the existing and past processes, identifying both strengths and weaknesses. Secondly, it allows a comprehensive assessment of patient flows, including a performance evaluation. Lastly, the analysis helps identify areas with potential for improvement and opportunities for optimization.

The first part of the analysis of the current and past situation consists of a description of the healthcare professionals that are involved in the pathways. It is essential to understand their tasks and activities to conduct the data analysis and draw conclusions.

The second part includes a description of the e-coach that is used in the virtual pathway. Through this description, we achieve a better understanding of the whole pathway and its corresponding weaknesses and benefits. This part is of high relevance to guarantee the comparability of this research, as there exist many e-coaches with various functionalities.

Lastly, we visualise the conventional and the virtual pathway using value stream mapping. Hereby we combine information from the previous parts and show the processes within the hospital. Thus, we depict the flow of patients and information. The outcome is a flowchart as well as a detailed description of every pathway.

### 3.2.4. Data Analysis

In order to compare the pathways, we conduct a data analysis to make conclusions based on the data information. In this section, we explain the methods that we apply and the corresponding experiments.

We carry out a descriptive and diagnostic data analysis by assessing different experiments based on hypotheses and future circumstances. Using this method we investigate the differences among the pathways and express them in terms of the KPIs defined in Chapter 2. We start the analysis by looking at the total number of appointments per patient, continue with the total appointment duration per patient and the total working time of healthcare professionals, and lastly investigate the costs.

We manually determine the costs by summing up the number or durations of various appointment types per patient as done below. An example for a patient is given in Appendix 3.2.

*(Total time TCs + Total time TC WK6 + Total time TC WK10)/60 * 55.44€*

*+ Number of TCVS * 96.52€ + Number of outpatient visits * 149.49€ + Costs E-coach = Total costs*

After identifying certain differences in costs between the experiments, it is crucial to ensure the statistical significance of these differences. This is achieved through the application of appropriate statistical analysis techniques, specifically conducting tests of significance. These tests help validate and confirm whether the observed differences in the KPIs are statistically significant or merely due to random variation. Therefore we carry out a two-sample t-test based on unequal population variances with a level of significance of 95% to test if the two cost population means are equal.

### 3.2.5. Experiment Design

The following section explains the experiments we carry out in our data analysis. This set of experiments is used to assess every KPI in order to achieve high comparability.

1. **E-coach: all appointments**

In this experiment, all appointments of patients of the e-coach group that are registered in the system are taken into account. This experiment includes administrative appointment (ADM) and hence represents the total number of appointments for healthcare professionals or when measuring time the total working duration of healthcare professionals.

2. **E-coach group: all appointments without ADM**

The second experiment considers all e-coach group appointments in which the patient is involved. It, therefore, represents the total number of appointments or the total appointment duration.

3. **E-coach group: all appointments without ADM and TCWK6**

The third experiment measures all e-coach group appointments except for ADM and TCWK6 appointments. This experiment is based on two assumptions: that the number of ADM appointments will decrease in future since the e-coach will be completely set up, and that Isala removes the scheduled telephonic consultation in week 6.

4. **E-coach group: all appointments without ADM, TCWK6 and 0.5 outpatient visits with a specialized nurse per patient**

The fourth experiment assumes, as experiment 3 that ADM and TCWK6 appointments are removed, and that the number of outpatient visits is 0.5 per patient (only every other patient has an outpatient visit). At the same time, we assume that no extra appointments are scheduled when removing TC WK6 and the outpatient visit.

5. **E-coach group: all appointments without ADM, TCWK6, and time of TCs limited by 80% per patient**

The fifth experiment assumes again that for the e-coach group all ADM and TCWK6 appointments are removed. Additionally, the TC appointments are reduced by 80% resulting in, on average, 7 minutes of TCs per patient. This experiment tests to what extent telephonic consultation needed to be reduced to be more costs efficient than the control group

6. **Control group: all appointments**

The last experiment takes all appointments of the control group into account. For the control group, we do not distinguish between the exclusion and inclusion of ADM appointments, since there is only one ADM appointment in the control group sample which does not affect the outcomes significantly.

#### 3.2.6. Assumptions

In this section, we state the assumptions we base our experiments and thus our data analysis on. The assumptions are crucial for interpreting and comparing the results correctly.

1. The appointment data is taken from the electronic patient record and was inserted when the appointment was planned. We assume that the appointments lasted the duration that was initially scheduled in the electronic patient record.
2. Since we do not have cost data for every type of outpatient visit, we assume that outpatient visits with the appointment codes NP, CP and NPT have similar costs as appointments related to the codes CPCVAVS, CPCVAWVS, CPCVAVPK.
3. For all experiments of the analysis we assume that the removal of an appointment does not cause more appointments of another type.
4. In the cost analysis we assume that the removal of an appointment leads to a cost reduction of that appointment of 100%.

### 3.3. Conclusion

In this chapter, we described the analysis methods of this research. We start carrying out a context analysis particularly focusing on the healthcare staff involved in the CVA patient treatment, the e-coach used in the virtual pathway, and the flow of patients and information. Afterwards, we conduct a descriptive and diagnostic data analysis to identify differences and their causes. We confirm the differences in the cost analysis using a two-sided t-test of significance. The data analysis is based on six experiments in which we compare different appointment constellations of the e-coach group to the control group. The results of the analysis are shown in Chapter 4.

# 4. Results

In this chapter, we demonstrate the outcomes of our analysis. Firstly, we show the findings of the examination concerning the past and present situation, specifically focusing on the e-coach, the various staff categories, and the pathways. Subsequently, we present and examine the results derived from the data analysis.

## 4.1. The E-Coach

Patients that follow the virtual pathway use an e-coach in addition to the normal rehabilitation training. The e-coach that the patients of our sample used is called “Luscii”. “Luscii” is a digital health platform that uses an app to monitor and measure patients at home. It is connected to the existing software of the healthcare institution.

Isala uses the e-coach for several patient groups. For every patient group, the e-coach can be set up differently. In the setup for CVA patients, the patients have to fill in several questionnaires every week regarding topics like fatigue, anxiety and depression. Based on the results of the questionnaires the patients receive automatic messages including certain modules with information about their condition. Additionally, the nurses in the VCC monitor the results of the questionnaires and contact the patient if needed.

Figure 1 shows a questionnaire regarding the topic of fatigue. The patient is supposed to indicate how much they suffer from fatigue. Figure 2 displays the related information module a patient could receive subsequently.

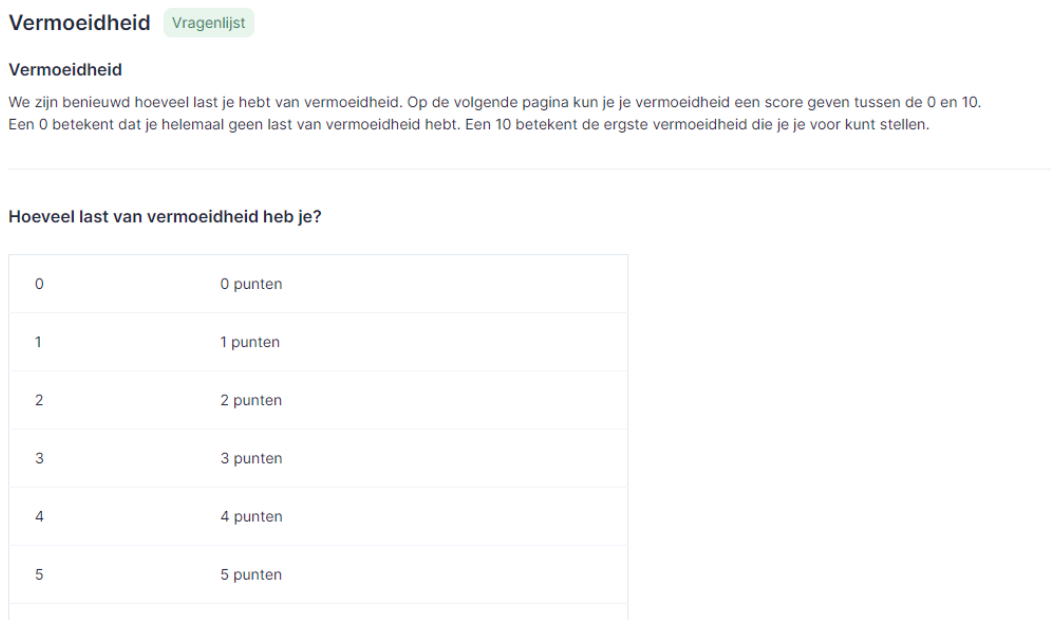


*Figure 1: Questionnaire of e-coach "Luscii" regarding fatigue*


*Figure 2: Information module of e-coach "Luscii" regarding fatigue*

## 4.2. Types of Staff

This section gives an overview of the types of staff involved in the CVA care pathways namely a neurologist, a specialized nurse and monitoring nurses.

**Neurologist**

The primary role of the neurologist revolves around inpatient treatments before a patient's discharge. As a result, the neurologist typically does not participate in outpatient consultations, unless there are exceptional circumstances where involvement is required alongside the specialized nurse.

**Specialized Nurse**

The specialized neurology nurse has gone through medical and nursing training and is specialized in neurology. He/She is involved in inpatient treatments and conducts outpatient/virtual visits with CVA patients. Additionally, the specialized nurse takes care of a weekly report sent by the monitoring nurses, and its follow-up actions, and is responsible for the content of the e-coach such as information modules. There is currently one specialized nurse for CVA patients in Isala Hospital in Zwolle.

**Monitoring Nurses**

The monitoring nurses are specialized in various other fields. They work in the VCC and are responsible for scheduling appointments, giving telephonic consultations and writing the weekly report for the specialized nurse. The monitoring nurses also monitor other types of patients next to CVA patients. At Isala in Zwolle, there are currently six monitoring nurses of whom three to four work every day.

## 4.3. Explanation of the Care Pathways

The care pathway we examined in this case study focuses on individuals that developed a cerebrovascular accident and experienced mild brain damage as a result of their stroke. These damages typically result in disabilities such as impaired speech and restricted physical abilities (*Effects of Stroke | American Stroke Association*, n.d.). Therefore patients typically go through a rehabilitation phase after the occurrence of a stroke in order to reduce the effect of the brain damage and relearn functions needed for everyday life. Patients that have experienced severe brain damage are usually sent to a rehabilitation institution to follow a more extensive rehabilitation program and do not follow this pathway. In this pathway, the rehabilitation phase always includes training with a physiologist and a speech pathologist. In individual cases, the patient can receive other training in addition to these. In the Chapter 4.3.1. and 4.3.2. we describe the two versions of this pathway: Firstly the conventional

pathway which was taken before the implementation of an e-coach and then the virtual pathway which can be taken optionally since 2020.

### 4.3.1. The Conventional Pathway

Before the implementation of the VCC, patients used to follow the conventional pathway for rehabilitation from a stroke, as visualized in Figure 3. The patient completed their inpatient treatment by being discharged from the hospital. Then patients returned home and started the rehabilitation process, engaging in various training activities. After six weeks, the patient had another scheduled outpatient visit with a specialized nurse at the clinic to discuss the rehabilitation progress and further procedures. Afterwards, the patient went through another six weeks of rehabilitation. After twelve weeks the patient had a final outpatient visit with a specialized nurse and was then transferred to the general practitioner. At this point, Isala's rehabilitation pathway was finished.

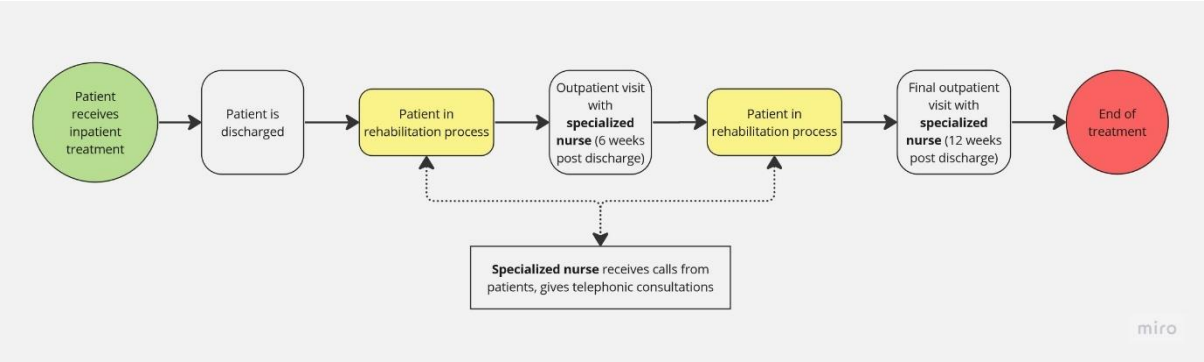


*Figure 3: The conventional pathway*

### 4.3.2. The Virtual Pathway

With the implementation of the VCC in 2020, the virtual pathway was introduced (Figure 4) that provides the possibility to be supported by an e-coach during the rehabilitation phase. In this pathway, the patient is discharged from the hospital following a consultation in which they are provided guidance on how to use the e-coach effectively. A twelve-week rehabilitation period follows in which the patient receives training and makes use of the e-coach to receive further instructions on the rehabilitation and give feedback. During these twelve weeks, the patient receives three consultation calls from the monitoring nurses, in weeks one, six and ten. The monitoring nurses also monitor the feedback that patients return to the e-coach. In case the feedback seems concerning, e.g. if the results indicate typical symptoms like anxiety, tiredness or depression, the monitoring nurses contact the patient via message or call.

Every Friday, the monitoring nurses send a weekly report to the specialized nurse. This report includes the patient record of all patients that finished the treatment with the specialized nurse and questions about individual patients that the monitoring nurses want to consult the specialized nurse about. The specialized nurse then forwards the patient records to their general practitioner and gives feedback to the monitoring nurses or contacts the patients themself. When the patient record has been forwarded to the general practitioner the pathway is finished and the patient is not able to use the e-coach anymore.

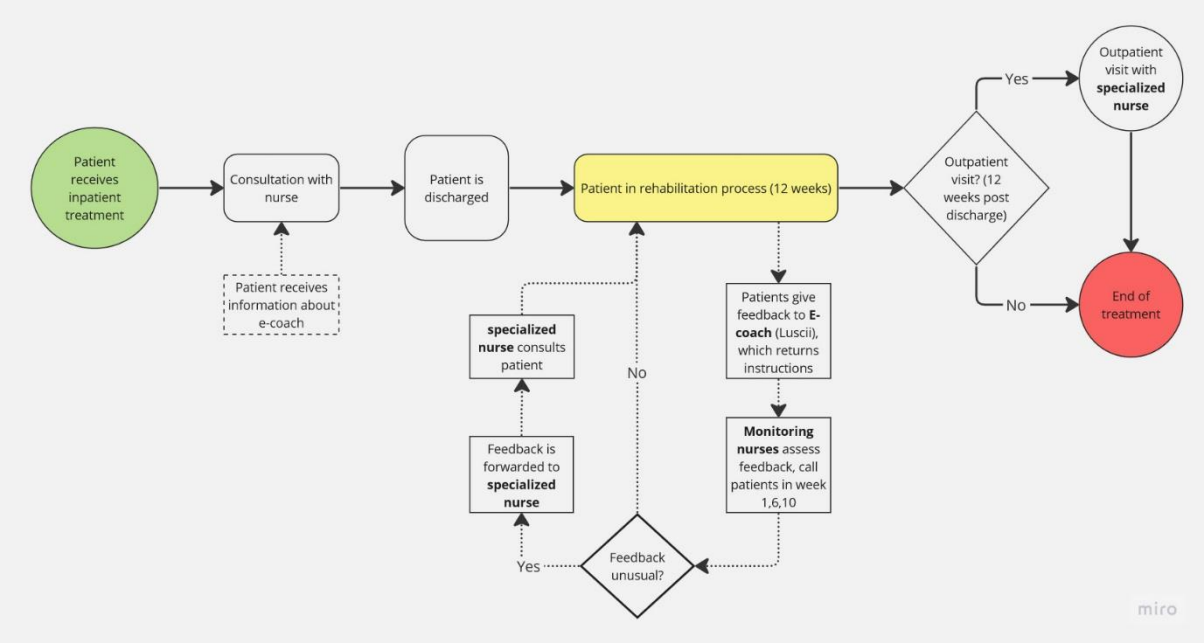


*Figure 4: The virtual pathway*

Ultimately, the pathways differ from each other by the number of outpatient visits and the monitoring during the rehabilitation phase. In the conventional pathway, patients were not monitored except for the outpatient visits in weeks six and twelve, which led to an increased number of calls from patients that felt insecure about the progress of their rehabilitation. In the virtual pathway patients are constantly monitored through the e-coach and only have an optional outpatient visit at the end of week twelve.

## 4.5. Data Analysis

In this section, we present the results of the data analysis. After cleaning the data and describing the demographics, we conducted a performance comparison analysis of the conventional and the virtual pathway as described in Chapter 3, looking at the total number of appointments per patient, the total appointment length and the working time of healthcare professionals per patient and lastly assessed the total treatment costs per patient. In this chapter, we present and interpret the outcomes of the data analysis.

### 4.5.1. Data Preparation

According to Chapter 3, we performed a data cleaning process. Table 3 shows the results concerning the patients' data sample.

*Table 3: The data cleaning process for the patients datasheet*

| | **E-coach Group Patients** | **Control Group Patients** |
|---|---|---|
| Total | 163 | 238 |
| Patients with 0 appointments | 1 | 105 |
| **Final number of patients** | **162** | **133** |

Table 4 shows the outcomes of the cleaning process of the appointment sheets.

*Table 4: The data cleaning process for the appointment datasheet*

| | E-coach Group Appointments | Control Group Appointments |
|---|---|---|
| Total | 884 | 292 |
| Physiology appointments | 95 | 156 |
| Parkinson appointments | 1 | 5 |
| **Final number of appointments** | **788** | **130** |

Based on the results of the data cleaning process we conducted the data analysis.

### 4.5.2. Demographics

By examining the demographic composition of our total sample population, we observe that the e-coach sample includes 163 patients of whom 39% per cent are women and 61% are men with an average age of 64 years. The control sample contains 46% women and 54% men with an average age of 73 years.

### 4.5.3. Number of Appointments

The first KPI we assessed is the total number of appointments per patient and the type of appointment. Figure 5 shows a comparison of all experiments. Experiments 1 to 5 are related to the e-coach group and experiment 6 refers to the control group.

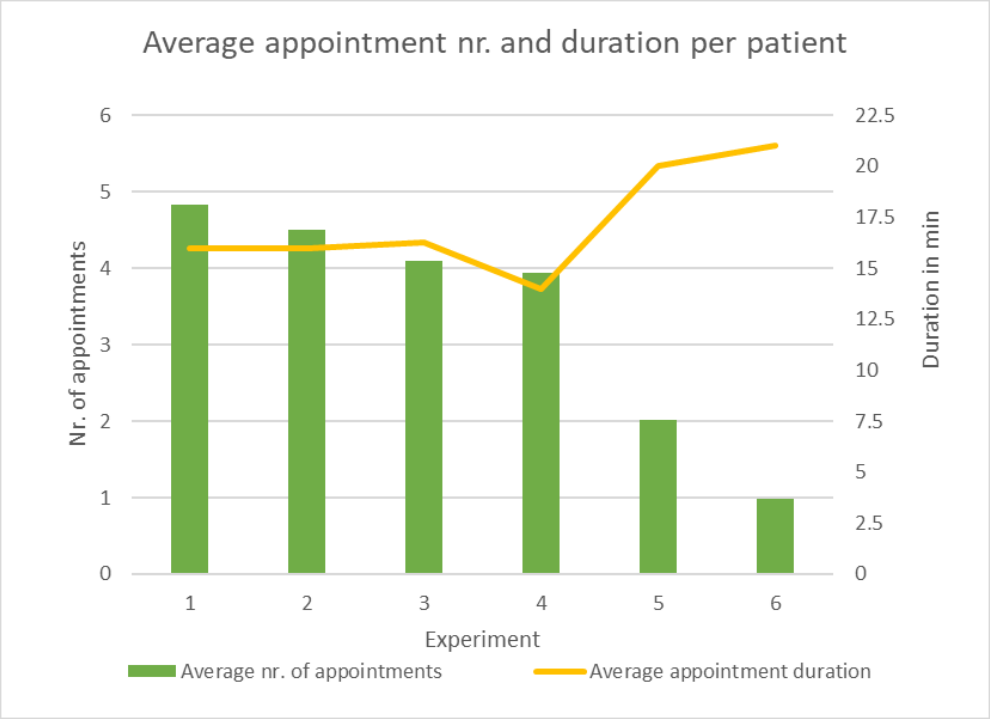


*Figure 5: Comparison of the number of appointments and the average appointment duration*

The average total number of appointments per patient ranges from 1 to 4.8 while experiment 1 shows the greatest and experiment 6 the lowest average number of appointments. The data reveals that, on average, patients in the e-coach group have approximately four times as many appointments compared to patients in the control group, except in experiment 5. At the same time, the average appointment duration for experiments 1 to 4 ranges between 14 and 16 minutes, whereas experiments 5 and 6 have an average appointment duration of 20 and 21 minutes respectively. We conclude that patients of the e-coach group have currently more than 4 times as many appointments as patients of the control group, while their appointments take, on average, 5 minutes less.

Experiment 5, in which telephonic consultations (TCs) are reduced by 80%, shows that the high number of appointments and the average duration of the appointments is related to the TCs.

To gain a better understanding of the type of appointment contributing to the overall high number of appointments, we investigate the breakdown of appointment types. Considering that our samples are of different sizes, we analyse the average number of appointments per patient based on different appointment types.

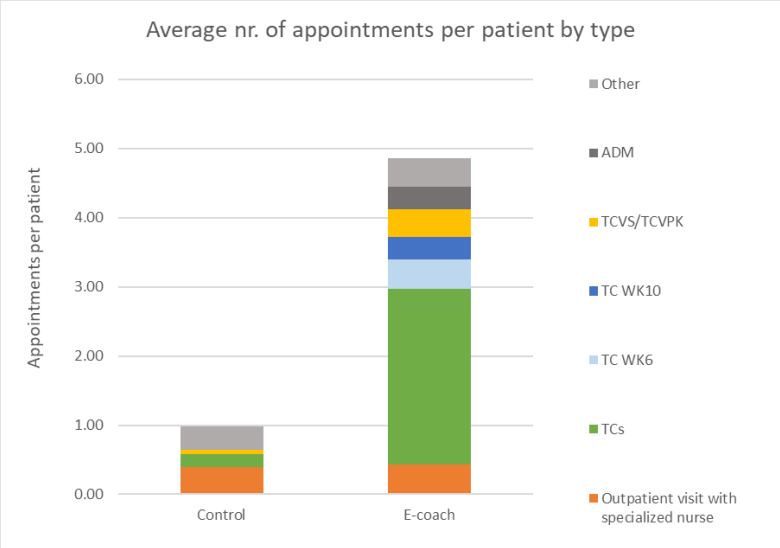


*Figure 6: Average number of appointments per patient by type of appointment*

Figure 6 shows a breakdown of the average number of appointments per patient based on the type of appointment. We observe that the majority of appointments of the control group belong to the categories of "other" and "outpatient visits with specialized nurse", whereas, for the e-coach group, most appointments are TCs (approx. 50%). This confirms that the great number of appointments of patients in the e-coach group is directly related to TCs.
Moreover, in both sample groups, around the same proportion of appointments are outpatient visits with a specialized nurse. The objective of the implementation of the e-coach was to reduce outpatient visits and their associated costs and conduct these appointments as telephonic appointments (TCVS/TCVPK), however, the breakdown of the appointments does not show a reduction in outpatient visits. Ultimately, most telephonic consultations were added to the number of appointments that existed before the implementation of the e-coach. Nevertheless, figure 6 solely represents the absolute number of appointments and does not provide full information regarding the actual total appointment duration.

### 4.5.4. Total Appointment Duration and Total Working Time

To gain insights into the time patients and healthcare staff spend on appointments, we compared the total appointment durations with each other. Once again, conducted an assessment of every experiment described in Chapter 3. Figure 7 shows a comparison of the total appointment durations per patient and a breakdown by appointment type.

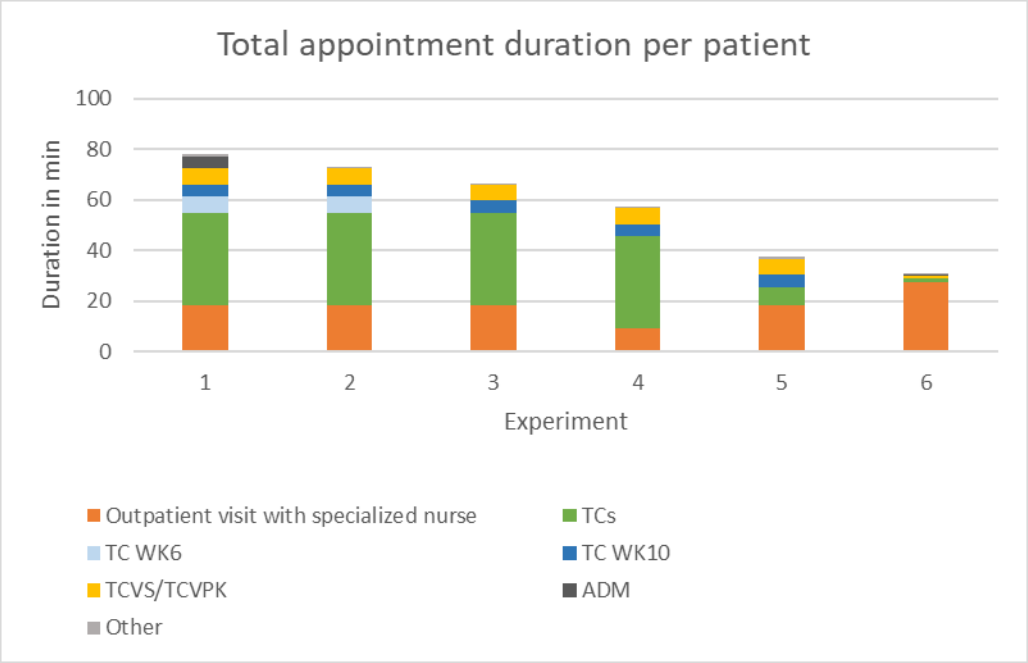


*Figure 7: Comparison of the average total appointment duration*

We observe that the average total appointment duration in all e-coach experiments is greater than in the control group experiment. Moreover, it shows that the TCs make up the largest part of the total appointment duration in experiments 1 to 4. The total duration decreases by 1/3 when reducing the telephonic consultations by 80%, as seen in experiment 5. When considering experiment 1, where all appointments are taken into account representing the total working time per patient, it can be concluded that staff members spend more than 2.5 times the amount of time on patients who follow the virtual pathway compared to those who follow the conventional pathway.
Assuming that Isala removes the fixed telephonic consultation in week six (experiment 3) the total appointment duration decreases by 15%. Nevertheless, the patients of the control group have at least half of the e-coach patients' total appointment duration, which can be related to the overall great number of appointments recorded.

### 4.5.5. Cost analysis

This section shows the results of the cost analysis. Since we do not have information about the costs of ADM appointments, we disregard experiment 1 for the cost KPI.

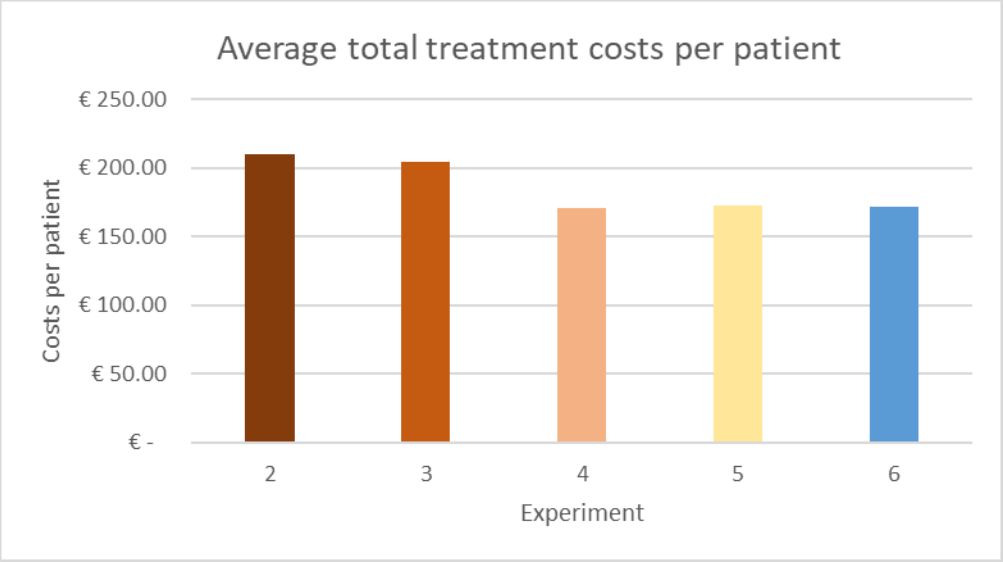


*Figure 8: Comparison of the average treatment costs per patient*

Figure 8 shows that total treatment costs per patient are the greatest in experiment 2 with 210€ per patient which is about 20% higher than the costs of the control group (172€). In experiment 3, where TCWK6 appointments were eliminated, patients achieve slightly lower costs compared to those in experiment 2, amounting to approximately €204. In experiment 4, patients achieved the lowest costs at around €171 per patient. Experiment 5, which involved an 80% reduction in the total time of telephonic consultations per patient in addition to the removal of TCWK6 and ADM appointments, resulted in total treatment costs of €173. Ultimately, the virtual pathway is only as cost-efficient as the conventional pathway in experiments 4 and 5.

To assure the difference in costs is not caused by a random variation in the samples we conducted a two-sided t-test for the means of the costs distributions with a 95% level of significance. Subsequently, we proved that the means of experiments 2 and 3 are different compared to experiment 6 with a 95% level of significance. On the other hand, we confirmed that the population means of experiments 4 and 5 are not statistically different to the mean of experiment 6, again with a level of significance of 95%.

## 4.6. Conclusion

In this chapter, we presented the results of the context and data analyses. We showed that the pathways mainly distinguish themselves by the number of planned outpatient visits and the implementation of the e-coach. Moreover, in the virtual pathway, the monitoring nurses take over tasks from the specialized nurse.

We observed that patients of the e-coach sample group have on average 4 appointments, whereas patients of the control group only have 1. The average appointment duration is 16 and 22 minutes respectively. When examining the total appointment duration per patient, we observed that the average total appointment duration in all experiments of the e-coach group is greater than that of the control group. Moreover, the breakdown by the type of appointment showed that the number of outpatient visits remained the same after the implementation of the virtual pathway. The comparison of the different experiments of the total costs per patient showed that the costs range between 171€ and 210€ in all experiments. The costs of patients of the e-coach group break even with the costs of the control group in two experiments: in experiment 4, which excludes ADM and TCWK6 appointments and assumes on average 0.5 outpatient visits per patient, and in experiment 5, which

excludes ADM and TCWK6 appointments and assumes a reduction of telephonic consultations by the VCC 80%. We observe that a cost reduction mainly takes place if the number of outpatient visits is reduced since outpatient visits have the highest costs.

Ultimately, the conventional pathway performs better than the virtual pathway in terms of the total number of appointments, the total working time of healthcare staff and the total appointment time. The virtual pathway only performs equally well as the conventional pathway when considering experiments 4 and 5 of the cost analysis.

# 5. Conclusion & Discussion

We conclude that the virtual pathway in its current state performs worse than the conventional pathway from a capacity management perspective for our case study of stroke patients in Isala. Our findings indicate that patients in the e-coach group, on average, have more than four times the number of appointments compared to patients in the control group. Even when considering an experiment where the VCC removes the planned virtual appointment in week 6, the average number of appointments per patient decreases by approximately 10% and thereby remains higher compared to the control group. However, appointments of the control group are on average around 37.5% longer than appointments of the e-coach group. When investigating a breakdown of the type of appointments we discovered that the average number of outpatient visits with a specialized nurse per patient remained the same after the implementation of the e-coach. The majority of the appointments of the e-coach sample can be identified as unplanned telephonic consultations executed by the VCC. Additionally, other planned telephonic consultations contribute to the great number of appointments of the e-coach group patients.

To get more insights into the actual time that patients and staff spend on appointments we assessed the average total appointment duration, in other words, the average of the sum of all appointments of one patient. To measure the total working time for one patient we took all appointments, including administrative appointments, into account. The results show that the average total working time for a patient of the e-coach sample is 2.5 times higher than for a patient of the control group. In experiment 3, where we assume that one scheduled telephonic consultation is removed, the actual appointment time per patient remains twice as high for e-coach patients compared to control patients.

Lastly, we conducted a cost analysis, considering five different experiments for the e-coach group. Only experiments 4 and 5, for which all administrative appointments and one planned telephonic consultation were removed and the outpatient visits or telephonic consultation duration limited to on average 0.5 or 7 minutes respectively, resulted in approximately equal treatment costs (172€, 173€) per patient than for patients of the control group (172€). The costs can be explained by comparing the total costs with the breakdown of the type of appointments and the costs per type of appointment. We observe that outpatient visits have the highest costs out of all appointment types. Since we discovered that the number of outpatient visits per patient remained the same after the implementation of the virtual pathway, we can subsequently only measure higher treatment costs per patient for the e-coach sample than for the control sample, unless we reduce the number of outpatient visits as in experiment 4 or reduce the number of telephonic consultation almost completely.

To achieve a virtual pathway that is as cost-efficient as the conventional pathway, Isala would need to adopt certain measures. One option is to limit the average number of outpatient visits to 0.5 per patient since they contribute significantly to the costs. Alternatively, they could reduce the average duration of telephonic consultations by 80%. Ultimately, the first option seems more reasonable if Isala plans to continue integrating digital healthcare into its systems while maintaining a high level of healthcare. The second option reduces telephonic consultations to such an extent that the virtual pathway closely resembles the conventional pathway.

Isala implemented the virtual care pathway for CVA patients in 2020 with the objective to create extra capacity for an increasing number of patients and to save costs. From our analysis, we can deduce that the virtual pathway in its current state does not create capacity and neither reduces costs. The main reason for this is the remaining high number of outpatient consultations. However, according to Yu &

Bayram (2021), CVA patients are eligible for virtual care since they are controlled patients and their appointments do not necessarily require physical interaction. We showed that virtual appointments are on average around 37.5% shorter compared to conventional appointments, which aligns with the findings of Tan et al. (2020) who concluded that, on average, virtual appointments are 26% shorter. Moreover, as the research of Peters et al. (2022), we conclude that virtual care reduces costs depending on the amount of care provided.

Hence, we provide a conclusive answer to our main research question: what is the impact of a virtual rehabilitation pathway from a capacity management perspective? Our findings indicate that the virtual pathway in its current state for our case study has a negative impact on the capacity performance of the hospital, as more appointments are conducted, more time is spent on each patient and the total treatment costs are higher. Nevertheless, we showed that virtual pathways have significant potential to generate capacity and yield cost savings when fully implemented. According to our research, comprehensive implementation of virtual care pathways includes a reduction in outpatient visits and a broader transition towards virtual appointments. In general, the impact of a virtual pathway on capacity performance depends among other factors on the extent to which outpatient visits are reduced. We also showed that patients using the virtual pathway have a greater number of contact moments with healthcare professionals which could increase the quality of care.

The results of our research are limited by several points. Firstly, the data we used was gathered through the electronic patient record, which is filled in by doctors and nurses. The purpose of it is to keep track of a patient's history rather than extracting data for research purposes. Our results rely on the completeness of this data. Besides that, we need to be aware of the small sizes of our samples. The small number of patients we analyzed reduces the reliability of our research as a sample bias could have occurred. Secondly, we simplified the cost scheme for the control group as it included many different appointment types for which we were lacking cost information. Some appointments were not conducted by specialized nurses and thus the total costs for the control group could be even lower. Lastly, in the experiments we considered, we assumed that when removing appointments, the total costs associated with those appointments would be deducted. However, in reality, not 100% of the costs are cancelled out, since some costs like facility costs remain when removing one appointment.

The research design employed in this study fulfilled its purpose of highlighting capacity performance differences among the pathways based on two samples. However, several factors could enhance the research design. Firstly, incorporating an enhanced data collection strategy would significantly improve the quality and quantity of the data gathered. This would lead to a greater number of data points and larger sample groups, ultimately improving the overall validity of the research findings. Furthermore, adopting a more precise and accurate cost scheme would reduce the reliance on assumptions, thereby enhancing the reliability of the research.

For more insights into the effects of virtual care pathways on capacity performance, this research could be extended in several ways. Firstly, the research could be conducted over a longer period of time or expanded to other patient groups. This would result in conclusions that take the long-term effects of interventions into account, e.g. the development of the number of outpatient visits, and increase its generalizability. In addition, more KPIs could be used to investigate a wider range of factors. Here, qualitative factors could be taken into account. Furthermore, conducting a collaborative research project to evaluate the effects of virtual pathways on hospital capacity and the quality of care and their interdependencies would serve as an extension to the present study.

The findings of this research hold valuable implications for hospitals that have already implemented or are planning to implement virtual care pathways. These outcomes draw attention to the potential

effects of virtual care pathways on costs and capacity, offering insights into key considerations for successful implementation.

To the VCC of Isala, we recommend continuing to treat patients with the virtual care pathway while reducing the number of outpatient visits. Virtual monitoring and appointments with the use of an e-coach have great potential as they increase the quality of care and can lead to cost reductions when virtual appointments are extensively utilized and the pathway is fully established. We hope this research contributes to a better healthcare system and scientific research in healthcare.

# Appendix

## Appendix 1.1

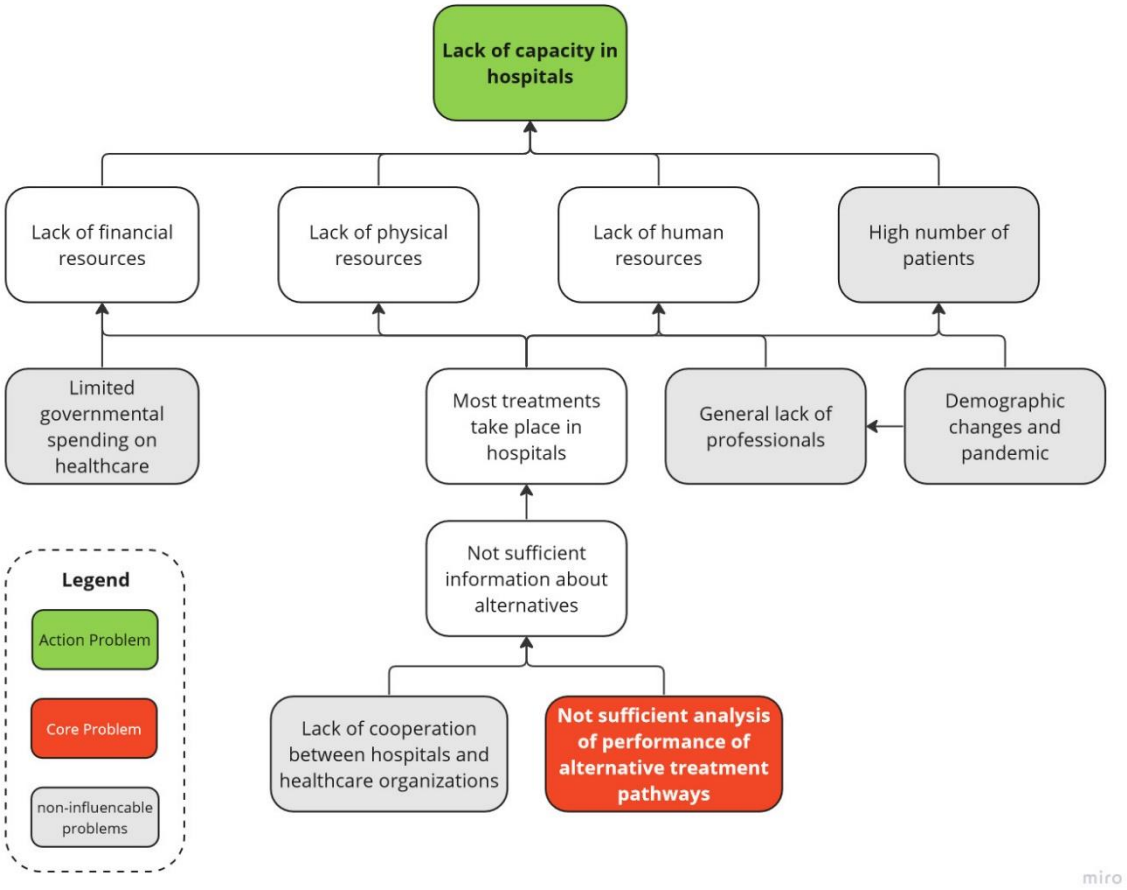


*Figure 9: The problem cluster*

# Appendix 2.1.

*Table 5: Record of systematic literature review*

| Date | Database | Search String | Results | Article Name | Author | Mentioned KPIs | Comments |
|---|---|---|---|---|---|---|---|
| May-23 | Scopus | TITLE ( *hospital* AND *capacity* AND *assessment* ) | 47 | A mixed integer linear programing approach to perform hospital capacity assessments | Robert L Burdett, Erhan Kozan | The total number of patient treated within a specified time period | |
| | | TITLE (*capacity* AND *hospital* AND assessment OR planning ) | 126 | Budget impact analysis of providing hospital inpatient care at home virtually, starting with two specific surgical patient groups | Guido M Peters, Carine J M Dogeen, Wim H van Harten | Investment costs, fixed costs, variable costs | only cost analysis |
| | | ( TITLE ( *capacity* AND *hospital* ) AND TITLE-ABS-KEY ( *performance* AND *measure* OR *kpi* ) ) | 25 | Five year trend analysis of capacity utilization measures in a teaching hospital 2008-2012 | Seyed Masoom Masoompour, Peyman Petramfar, Puya Farhadi, Hamideh Mahdaviazad | length of stay, bed turnover bed occupancy rate, turnover interval | |
| | | | | Optimizing nurse capacity in a teaching hospital neonatal intensive care unit | Ali Kokangul, Serap Akcan, Mufide Narli | admission number, occupation rate, satisfaction rate | Find optimal nurse capacity |
| | | ( TITLE ( capacity AND hospital ) AND TITLE-ABS-KEY ( measure OR kpi ) ) | 126 | A comprehensive county level model to identify factors affecting hospital capacity and predict future hospital demand | Tanmoy Bhowik, Naveen Eluru | hospitalization rate, intensive care unit rate | |
| May-25 | Pubmed | (TITLE ( *capacity* OR *capability* AND *hospital* ) AND TITLE-ABS-KEY ( *virtual* OR *tele** ) ) | 40 | The influence of telemedicine on capacity development in public primary hospitals in china: A scoping review | Junyue Zhang, Qingjun Lu, Leiyu Shi | discharged patient number, hospitalization cost | no further explanation |
| | | | | Telerehabilitation Intervention in Patients with COVID-19 after Hospital Discharge to Improve Functional Capacity and Quality of Life. Study Protocol for a Multicenter Randomized clinical trial | Jose- Manuel pastora -Bernal et al. | direct costs (costs related to clinical aspects), indirect costs (costs related to the use of technology) | mainly focused on quality of treatment |
| May-27 | Other | found via other articles | | Performance measurement criteria in health care organizations: Review and future research directions | L.X. Li, W.C. Benton | length of stay, patient costs per day, total costs per case | part of internal quality measures |
| | | | | Telehealth: A path to virtual integrated care | J. Augenstein et. Al. | readmissions, treatment time | |
| | | | | Modeling patient flow in an emergency department under covid-19 pandemic conditions: a hybrid modeling approach | G. Terning et Al. | length of stay, waiting time, occupancy | |
| | | | | Emergency department quality dashboard; a systematic review of performance indicators, functionalities, and challenges | S. Almasi et Al. | number of patients discharged, patients' mean length of stay, number of consultations given, number of beds available | |
| | | | | A decisison support simulation model for bed management in healthcare | E. Cudney et Al. | admissions, length of stay, waiting time, queue time | |
| | | | | Simulation modelling of patient flow and capacity planning for regional care needs: a case study | K. Bae et Al. | length of stay, waiting time, occupancy, | |
| | | | | An electronic dashboard to monitor patient flow at the Johns Hopkins Hospital: Communication of Key Performance Indicators using the Donabedian model | D. Martinez | length of stay, number of discharges, readmission rate | |

## Appendix 3.1.

*Table 6: Breakdown of Cost Components*

| Type of cost (Activity Code) | Costs | Description |
|---|---|---|
| Outpatient visit (190013) | 149.49 € | Outpatient clinic visit with a specialized nurse |
| Virtual visit (190162) | 96.52 € | Consultation call with the specialized nurse that replaces an outpatient visit |
| Monitoring and telephonic consultations | 55.44 €/hour | Salary for an hour of work of monitoring nurses in VCC regarding CVA patients |
| E-coach software license | 43,822.1€ (21.81€) | Total costs of the license of "Luscii" for all CVA patients. (Costs per patient, assuming 2/3 of CVA patients use e-coach) |

## Appendix 3.2.

*Table 7: Example of the number of care activities per patient and related total costs*

| Patient | Total time TCs | Total time TC WK6 | Total time TC WK10 | Number of TCVS | Number of Outpatient visit | Costs E-coac | Total costs |
|---|---|---|---|---|---|---|---|
| 1 | 25 | 0 | 0 | 1 | 0 | € 21.81 | € 141.43 |
| 2 | 15 | 15 | 15 | 0 | 1 | € 21.81 | € 212.88 |

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