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VULNUSMON – ASSESSING A DIGITAL BANDAGE AS AN EXEMPLARY PROJECT FOR DIGITAL TRANSFORMATION IN THE HEALTHCARE INDUSTRY

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Abstract

Digitalization in healthcare continues to advance. This work presents a project focused on developing a digital bandage to monitor chronic wounds, *"vulnusMON"*. It aims to increase efficiency and to enhance conditions for healthcare workers. After examining aspects of technology, assembly, sustainability, and society, the conclusion that the project should be pursued is drawn, accounting for different perspectives of medical staff and patients. Data is transferred wirelessly through Bluetooth Low Energy and LTE-M with several security measures to diminish the risk of privacy issues. To preserve the environment, the digital bandage is composed of partly reusable electronic components, such as sensors.

Keywords: Digital transformation, digital healthcare, wound monitoring, innovative healthcare solutions

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BLE	Bluetooth Low Energy
GDPR	General Data Protection Regulation
IoT	Internet of Things
LoRa	Long Range
L&R	Lohmann & Rauscher
MCL	Maximum Coupling Loss
NGO	Non-governmental organization

1. Introduction and relevance – Group part

Increasing life expectancy, the growing number of care cases, and too few caregivers - the demographic development and the resulting **nursing bottleneck** have been dominating topics in Germany for decades. For the longest time, politicians and the healthcare system did not pay a lot of attention to the challenges, compounding the effects on future generations.

It is evident that **innovative solutions** must be provided to reduce costs and increase the capacity of the nursing staff. Otherwise, a collapse of the healthcare system will be inevitable (Ernst & Young 2019). **Digitalization** will overall transform the communication between professionals and patients, as treatments can be specialized more accurately for each individual. **Technology and data** are enabling the provision of care for patients in a completely different way by being more convenient, allowing more precise diagnosis, and overall reshaping the work pattern, up to reducing costs since tailoring individual medicine for specific needs is enabled (Bocas 2022).

The importance of digitalization in the healthcare system is emphasized by overall **growth and funding**. The sector has grown into an $8 trillion industry, mutually growing a need for improved research and technology, as there is a lot of potential for innovation (Allen 2021). Looking at the number of **patent applications** in Europe in 2021, medical technologies, with over 15.000 patent applications in a total of 38 countries, are placed second after digital communication, representing a 0.8% increase from the previous year (European Patent Office 2021).

Despite all that, the increasing use of digitalized tools within the healthcare industry must not shield the associated risks: Given the intimacy and sensitivity of the data that is transferred, the demand for **secure data transmission and protection** against data leaks becomes essential. In the first six months of 2022, there were more than 19 million records implicated in data breaches,

emphasizing the need for thorough **security measures** in order to provide a reliable protection pattern (McKeon 2022).

This work project aims at evaluating the challenges and opportunities of digital transformation in the healthcare industry by the example of **vulnusMON** – a project initialized in 2017 to develop a digital bandage. The **purpose of this work is twofold**: One, to provide a thorough analysis of the stakes of implementation of the project, and secondly, based on this, to give a profound estimation on whether the project should be fulfilled and if so, under which circumstances.

The thesis is structured as follows: In chapter 2, an introduction to digital transformation and digital transformation in healthcare is given, with a focus on wound monitoring and current solutions, since it is of high relevance for vulnusMON. Chapter 3 will be devoted to giving a profound knowledge of the vulnusMON project. In the following chapters, three topics that require the most attention when launching vulnusMON will be elaborated on: first, **technological aspects** concerning data transfer and data privacy, secondly the **assembly of the bandage** and the sustainability thereof and lastly, the **acceptance** of potential patients and their barriers to the utilization of the digital bandage. Chapters 8 and 9 conclude the analysis by discussing several aspects as well as giving a **future outlook**, inter alia, taking into account expansion strategies.

2. Background Information – Group part

To analyze the project of vulnusMON, it is important to understand the challenges and impact of digital transformation on the healthcare industry which will be presented in the following.

2.1 Digital Transformation

One clear definition of digital transformation is not given in literature. Often, it arises together with the two terms "*digitalization*" and "*digitization*". Verhoef et al. (2017) show that

digitalization, digitization, and digital transformation are the three stages in order for overall digital transformation to occur (7). It is the process during which the change from analog to digital form happens (Gartner n.d.) and can be for "*all information types (texts, sounds, visuals, video and other data from various sources)*". This specific process can be referred to as **digitalization** (Machekhina 2017)**.** While digitalization can arise in a company as a single digitalization project, **digital transformation** requires multiple of such projects, to change the business (Bloomberg 2018). Meanwhile, **digitization** is described to be the **driver of disruption** of the "*established business rules*" (Gimpel and Röglinger 2015, 5). These changes are driven by digital technologies. **Technological advances**, such as computing and connectivity, allow innovations within organizations to happen and create an opportunity for **competitive advantage** (Vial 2019).

2.2 Current challenges of the Healthcare Industry

The World Health Organization (2021) states that by 2030, there will be 15 million **health workers missing** worldwide. Likewise, the US National Library of Medicine notes that in the US alone, more than a quarter million additional nurses are needed (Haddad, Annamaraju and Toney-Butler 2022). The resulting **staff shortage** may be led back to missing investments in education and training, as well as the misallocation of existing staff (World Health Organization 2016). In 2021, there have been more than 35.000 unfilled positions in healthcare in Germany (McGrath 2021). The Health Services Expert Commission (CESI) has acknowledged the fact of shortage in 2019, alongside the increase of **demand in long-term care**, versus the reduction for inpatient and outpatient care.

The **Covid-19 pandemic** has enhanced the **pressure** on healthcare workers even more. On the one hand, high-risk encounters on the front line increased the stress for all people working in the industry, when the healthcare systems were already at a limit of resilience. This led to having

nurses taking care of more than twice as many patients as per norm (Balasubramanian 2022) and is accelerated by the fact that payment remains rather low, failing to acknowledge the value and impact of these jobs. The pandemic may have increased **society's awareness** of the conditions of healthcare workers, but the conditions are impeding making the industry attractive to potential applicants whatsoever. It is for this reason that the German government has included a new plan for increasing personnel in the industry in their coalition agreement (Jeske 2021).

In the same way, the gravity of the lack of healthcare workers is stressed by the **continuous growth and aging of the population**, due to which the population will require more care (Boyle 2021). By 2050, the average age is projected to increase in all regions of the world. Thus, the staff shortage is critical to how healthcare is delivered.

Another challenge for the healthcare industry is the **increase of Artificial Intelligence (AI) and AI-based technologies**, implemented for either disease detection or aiming to prevent diseases. The value propositions are focused on "*self-care, preventive telemedicine, and disease prediction*" (Hermes, et al. 2020, 1044). However, the implementation of new technologies within the healthcare industry comes with great challenges, which will be further analyzed in the following.

2.3 Digital Transformation in the Healthcare Industry

A recent systematic review (Marques and Ferreira 2020), shows how much research on **digital transformation in the healthcare industry** has increased over the past two decades and highlights the most common technology-related research themes. Starting from wearables, tracking, or Big Data and AI, the scope of opportunities is extremely wide, displaying a big amount of **unexploited potential**. Even after lengthy hesitations, more and more digitalized projects are being implemented, thus driving the efficiency of the sector (Ascione 2021).

Key enablers that occur when healthcare is digitalized are, among others, expanding precision medicine, the transformation of care delivery, and an improvement of the patients' experience. That includes managing **data as a strategic asset** and empowering **data-driven decisions**, since all parties involved need to understand the importance of data and its advantages for decision-making. Also, care teams and their patients should be connected.

2.4 Digital Wound Monitoring

Recently, **wearable and digital monitoring** are becoming more and more relevant to today's society, especially due to the ability to monitor various physiological parameters of the body and their healing process (Farooqui und Shamin 2016). Nussbaum, et al. (2018) analyzed the impact of chronic wounds on the economy and associated expenses, stating that the **highest amount of expenses** is coming from hospital outpatients with **chronic wounds**. Tracking the healing process of each wound allows nurses and patients to redeem themselves from a certain inevitable investigation (Koebe 2022). Likewise, wearable wound monitors serve the purpose to inform about the **accurate and timely healing state** of wounds and clinicians can make decisions for treatment (Deng, Gould and Asam Ali 2022, 2560).

The sector of digital wound monitoring possesses a lot of unidentified potential. Nevertheless, an increasing number of companies are working on innovative solutions to fill this gap: Imito AG, for instance, launched a **wound-tracking app**, that uses visual images to track the progress of wounds (Imitio AG 2022). Other solutions include similar approaches, such as the usage of phone applications by patients in **postoperative scenarios** for wound monitoring (Gunter, et al. 2016; Gunter, et al. 2018; Scheper, et al. 2019). The application captures key wound characteristics with pictures of the wounds taken by the patients themselves (essity 2021).

For **chronic wounds**, the healing process is more complex. Wound assessment, today, primarily takes place in laboratory environments which are high in cost (Brown, Ashley and Koh 2018). To **overcome these challenges** and to change the way care is delivered, companies are innovating ideas and projects – still only a few exist so far. The project VeCare, as an example, collects data through a disposable bandage applied to chronic wounds. The bandage covers the wound and can measure, inter alia, the pH-level, and temperature of the wound (Coxworth 2021). Powered by a battery, the bandage can operate for about 40 hours in a row and shares the collected data with the health carrier's phone (Gao, et al. 2021).

After market research, it can be summarized that there are only a handful of companies that pursue the innovation of a digital bandage and are developing possible solutions. The advantages of wound monitoring are unmissable, reflecting, among other things, an innovative and financial benefit for the healthcare system. **vulnusMON** will be one of the innovative projects which will introduce a new direction – especially for the nursing market.

3 Developing a Digital Bandage: vulnusMON – Group part

The following chapter will illustrate the dynamic of the industry by the example of vulnusMON, now that the needed background on the current status of digitalization in healthcare has been provided.

3.1 Project overview

The project was initialized in 2017 and revolves around the **development of a digital bandage**. It has been sponsored by the German Federal Ministry of Research and Technology from 2017 to 2019. The project is still in the development stage, having only one prototype built so far

(Schulz 2022a). The name states “vulnusMON” (“*vulnus*” corresponding to the Latin word for wound and “*mon*” as in monitor) (vulnusMON 2022), however, this is subject to change.

The purpose of the project is to **reconceptualize the bandage** in its traditional form. As of today, a bandage’s purpose is to solely cover the wound that is to be healed, protecting it from external influences, for the healing process to be ensured. With the advancement of a digital bandage, these core functions remain, however, the bandage is also capable of **informing practicians** about the status of the healing due to monitoring with technological sensors. As of today, it is mostly used for **bedridden patients**. The collected data will be sanitized and collected in a **cloud**, being accessible for eligible nurses, practicians, and other healthcare workers on a **digital device** such as a tablet or computer, displaying all current patients and their respective wounds. This allows for same-level information distribution among all practicians without any time lag.

The benefits from a **medical perspective** are transparent: It is counterproductive to tear off a bandage too soon, since the naturally developed protective skin layer would be destroyed by the removal of the bandage. On the contrary, if a bandage is not changed at the right time and with precaution, inflammation, irritation, or other medical risks could arise, increasing the possibility of becoming even more severe than before.

On that note, chronic wounds must be treated over weeks or even months. Patients do not require to stay at the hospital for such a long-time span and can be dismissed (Schulz 2022a). For one, it would be too costly to have them stay in the hospital, secondly, they would require space that is needed for other patients with illnesses that ought to be taken care of on-spot.

By allowing **constant supervision** realized by multiple sensors transferring the relevant data, the digital bandage helps practitioners to decide on the timing of changing the bandage,

resulting in more efficient handling for the nurses on the one hand, and enhanced wound healing for the patient on the other hand.

So, the project is to be applied in two possible **use cases: Stationary and ambulant**. The stationary example revolves around integrating the digital bandage in hospitals with patients that are bedridden with wounds. The other use case is that of ambulant patients, that are at home with chronic wounds, being under supervision by a nursing service.

Currently, there are three institutions to function as a collaborative workforce for vulnusMON, combining expertise and resources: The Marien Hospital in Cologne, Germany to establish a profound knowledge in all matters related to medical knowledge; Lohmann & Rauscher, a German developer for the bandage and the material as well as the IT company q-beyond AG for matters regarding technology, cloud, and data transfer. The Fraunhofer Institute in Aachen as well as Maastricht University were consulted for research purposes. At this stage, the project is mostly oriented toward the **German market** (Schulz 2022a).

3.2 Functioning of the digital bandage

Wound monitoring happens in a process that requires **three steps.**

First, to be eligible for the program, an analog form is to be filled out in order to **evaluate** whether the patient and the wound are suited for bandage usage. 16 medical parameters are questioned, such as weight, potential pregnancy, and chronic diseases. According to the results, the corresponding practitioner ultimately decides on the eligibility of the patient. In a similar manner, a brief evaluation of technical aspects is taken place. Correspondingly, there are certain parameters to assess the suitability of the wound for the program, such as ABI-index, size of the wound, and duplex sonography (Q-Loud GmbH 2019).

Second, after being evaluated as suitable for the program, the patient will be added to vulnusMON by **registering generic data** such as gender, height, and corresponding practitioner.

The actual monitoring will commence with the third step, where medical rounds of the wound take place, thoroughly **documenting the stages of wound healing**. The patient states several aspects that are mostly perceived, such as pain, while several sensors in the bandage are monitoring and measuring various medical parameters that give elaborative information on the healing status of the wound, such as pH-value, temperature, size, and impedance. The collected data is clustered into a cloud system, showing the relevant information on a digital device for caregivers to treat the patient. Certainly, the mere display of parameters does not add the required value and efficiency. It is for this reason that algorithms should be put into place, in order to evaluate if certain conditions require action chains. For that, the collected data needs to be **clustered and analyzed** by priority to give a profound outline of the healing status.

To realize this promising value, data transfer needs to be coherent, and stable as well as to allow for algorithmic decision-making to give profound predictions. Concurrently, an alarm needs to be put into place if there is a lack of data reported, either by a technical fault or the physical shift of the bandage, making it impossible for the sensors to properly monitor the wound.

On that note, a tremendous challenge that ought to be regarded when implementing the digital bandage is the concern of **data security**. Working with digitalization in healthcare perforce means handling and transferring sensitive, personal data in great amounts which puts a thoroughly safe and impervious data transfer at the highest stake. The data is to be only accessible by authorized users, eliminating the threat of potential data leaks and protecting the patient's right of data privacy at any given moment. Evaluating **possible ways of data transfer including algorithmic decision making** as well as weighing the importance of **data protection and privacy** will be discussed in chapter 5.

On another note, **the assembly of the bandage** also needs to be analyzed. In its nature, a bandage is a disposable article, that is to be thrown away after each use for sterilization reasons. In the case of a digital bandage, however, this may not apply: Sensors need to be built into the material to measure properly. To have electronics thrown away every time that the bandage is changed would imply a huge amount of disposal, raising the question of sustainability and costs throughout the supply chain. Likewise, the question of **social sustainability** with regard to the development of the workforce in the healthcare industry arises. A paradigm shift from traditional nurses and doctors to what the human capital of a hospital might look like in the future is happening. The assembly of the bandage alongside the rising questions of sustainability within the production will be discussed in chapter 6.

Apart from this, the successful implementation of a digital bandage does not only comprise the technological and material matters, but equally important relies on the **perception of society** and the way people will react towards a digitized solution of such a traditional instrument in healthcare. Medical staff, such as doctors and nurses, that may work with this solution might have a different perception of the matter than the patients, to whom the digital bandage will be applied to. The perception might be influenced by factors, such as personal opinions on necessity, but also cost savings. These matters will be thoroughly discussed in chapter 7.

4 Methodology of the thesis – Group part

After considering the scope of the project, a sequential exploratory **mixed-method research approach** was chosen to develop this work. Specifically, alongside literature review, both qualitative and quantitative data have been gained.

For one, **three semi-structured interviews** have been conducted over a time span of three months with Prof. Dr. Ralf-Joachim Schulz, who is the head physician at the St. Marien Hospital

in Cologne and has been working on the development of vulnusMON. All interviews were conducted via Microsoft Teams, with each interview lasting from 40 to 60 minutes, and were held in German. They were recorded and translated later. Based on the discussions of the interview, **three separate research questions as seen in chapter 5 to 7** have been formulated to further elaborate on topics that show the most relevance in the development of vulnusMON.

Secondly, to collect **quantitative data**, a survey was created as an **online survey** using Microsoft Forms to understand society's mindset, acceptance, and concerns towards a digital bandage. As the survey was conducted online, it allowed anyone to access it via a link either on desktop, smartphone, or tablet. To increase the sample size and allow access to the survey, it was distributed via social media channels, such as WhatsApp, LinkedIn, and Instagram. Additionally, the survey was shared on the platform "SurveyCircle".

The survey was open for 4 weeks, resulting in a total of 111 participants. The questions aimed to evaluate the participant's willingness towards using a digital bandage, based on the Technology Acceptance Model (Davis 1989) and newer studies. For the participants of the survey, it was mandatory to answer all questions. Not answering all questions would result in a failed submission. The first part of the survey focused on the collection of socio-demographic data (Appendix 4), such as gender, age, and education, while the second part of the survey tested the measurement items listed in table 3 (Appendix 5). For the second part of the survey, which focuses on the perceptiveness of digital bandages, the **Likert Scale** was used for answer options. The results are presented in chapter 7.

5 Applying the Technology Acceptance Model - Society's perspective on a digital bandage – Pauline Schudrowitsch

The medical staff shortage and the decrease of staff available in the medical sector, impacting how healthcare is delivered, have been discussed in the introduction of the paper. It follows, that medical staff and healthcare patients have different motivations when it comes to the utility of technologies and specifically to the utilization and adoption of the digital bandage discussed throughout the thesis.

Focus is the utilization of technology by both, medical staff and potential patients, so society, will potentially wear a digital bandage at some point in time. The provided benefits mentioned in literature, especially in face of the current trends in healthcare, are analyzed, followed by giving an overview of **prerequisites** that the staff must meet to adopt and utilize technologies. To do so, a survey was conducted, and its outcomes and limitations are discussed throughout the chapter. The survey items have been based on the **Technology Acceptance Model** (Davis 1989), in order to present what factors can impact a person's perception and willingness to utilize and accept technologies.

7.1 Perception of the utilization of digital technologies of medical staff and patients

To provide an overview of the state of research on the perception of digital technologies and specifically digital bandages, this chapter is divided into two parts. First, medical staff are discussed and the prerequisites they must meet. Secondly, and with a higher focus, the patient's perceptions are explained.

7.1.1 Medical Staff

The usage and adoption of technology is an opportunity in order to deal with **staff shortage** and to "*gather actionable data to mitigate risk*" (Policymedical n.d.). The staff shortage can also be led back to insufficient staffing, which has been touched upon in chapter 2.2 more thoroughly. Staff, like nurses, also state that their **working conditions** are significantly high in stress levels and that working schedules are difficult (Crimm 2022). Linked to this argument it is stated that an appropriate remuneration system is needed (Moore et al. 2014, 31), since competitive salary is a driver of quality in healthcare (Sewe, Bula and Oringo 2018), but also needed for keeping the employees **motivated**, satisfied and higher in performance (Martono, Khoiruddin and Wulansari 2018).

When it comes to the application of **health information technologies** in medical organizations, the education of the medical staff is critical. On that note, after the technology has been purchased and deployed, the **staff** has to be **trained** on its utilization (Ajibade 2018). It is shown that it is essential to have doctors participate in the creation of those technologies (Diaz 2021), in order to have a positive impact on personal beliefs (Ketikidis, et al. 2012).

Linked to this, it can be stated that when it comes to the acceptance and utilization of new technologies in healthcare, nurses and doctors are found to be open to using them if it is found that those technologies **improve efficiency and task performance** (Rahimi, et al. 2018). Healthcare professionals believe that it is important to **collaborate** with patients when it comes to digital health (Jarva, et al. 2022). A prerequisite that must be met, is the willingness to use the digital service by the doctors, which can be led back to **competence** (1383). It follows, that the perception of the precise project vulnusMON must be tested, in order to gain an understanding if medical staff is open and willing to use the digital bandage, as a tool.

A possible counterargument on the deployment of a digital bandage in care is that healthcare professionals need to make decisions, not only based on **psycho-social needs** patients have. These are different from physical needs and can be fulfilled by personal contact (Moore, et al. 2014, 26), representing that competences, such as **interpersonal skills**, are also required besides professional and theoretical knowledge.

A problem that can be faced with the adoption of technologies overall is the lack of quality and amount of people that support digital transformation (Appleby, et al. 2021). In wound healing, additionally, the medical staff must meet **prerequisites**, such as a "*comprehensive understanding of the healing process*" (Deng, Gould and Asam Ali 2022, 2543). When it comes to vulnusMON, doctors and nurses must additionally be able to read and interpret the data provided by the bandage (Schulz 2022a).

Having a look at how medical staff utilizes technologies in wound care, one of the most recent studies, has been conducted by Karadag and Sengul (2021) in regards to **telehealth**. Official U.S. government websites define telehealth in healthcare as the usage of "*electronic information and telecommunications technologies to support long-distance clinical health care*" (The Office of the National Coordinator for Health Information Technology (ONC) n.d.). This can include **communication via the internet**, such as talking to healthcare professionals through video, texting, and remote monitoring (Health Resources & Services Administration 2022). The study by Karadag and Sengul (2021) shows that workers focusing on wound care in Turkey, as an example, have been allocated to take care of COVID-19 patients instead. With respect to **telehealth**, the authors found that the smartphone was used by 31.9% of doctors and by 27% of nurses. Videos and photos were more often sent by nurses (19.9%) than by doctors (17.3%). Though there are no numbers to compare it with pre-pandemic, especially taking the argument of re-allocation of medical staff into account, it could be likely that the amount of telehealth used throughout the

pandemic has increased, to be able to tackle multiple stations. An important mark to make is that the study by Karadag & Sengul (2021) was conducted throughout the pandemic, while the healthcare system was under pressure (Couarraze, et al. 2019) and faced different circumstances than in times outside of the pandemic.

7.1.2 Patients

Though it is the doctor's responsibility to decide for or against the usage of any kind of treatment, and vulnusMON, this chapter discusses what perceptions healthcare patients might have when it comes to the application of the digital bandage.

More and more consumers are willing to share their data and have their health monitored. Additionally, over the past years, more people are willing to use technologies to measure their health and fitness goals. Likewise, the utilization of technologies to **monitor health issues**, such as blood pressure, has also increased (Betts, Korenda and Giuliani 2020). The pandemic has also shown, that regarding chronic wounds and the lack of personal staff, some patients with chronic wounds encounter difficulties and wounds get infected increasingly due to the lack of care (Karadag and Sengul 2021).

Furthermore, interviews conducted within a study have shown that the **readiness to use digital health services** and their competencies are linked to **age**. Older age as an example, could be linked to worse digital skills (Jarva, et al. 2022, 1383). This is an important factor to note for vulnusMON. As the project is more targeted towards elderly people, as they are more likely to have chronic wounds (Schulz 2022a), it must be assured that they are educated on the purpose of the bandage. Though the doctors will decide if a bandage is applied or not, it is important to understand what the patients might feel going through the process, in terms of comfort and acceptance.

When it comes to the overall utilization of digital tools in health, a study has been conducted, targeting Swedish, Italian, Turkish, and Egyptian people. The results have shown that in all these countries, more than 50% of the people are willing to use digital tools in health. In Italy, the rate was the lowest at 56.4%, which the authors led back to the higher average age of survey participants (Carbonaro, Elsaied and Semerci 2021). Overall, 92% of respondents in a survey hope for digital transformation to improve the **patient experience** (Appleby, et al. 2021). Similar outcomes have been found when it comes to the utilization of technologies for at-home diagnostics (Betts, Korenda and Giuliani 2020).

Linked to age, especially older generations, such as Gen X, Baby Boomers, and Seniors are found to be more comfortable in telling their doctors they disagree with them than younger generations, such as Gen Z and Millennials (Betts, Korenda and Giuliani 2020). Patients like to participate in **decision-making** when it comes to helping over direct delegation of healthcare professionals. Recent research has shown that it is important to understand what patients might think about treatment and to indeed incorporate them in the decision-making of how care will be provided (Agarwal, et al. 2020). For these reasons, the survey conducted, which will be presented in the following chapters, focuses on the **perception of potential patients**.

7.2 Survey on society's perception of a digital bandage

This chapter aims to present the survey’s model that has been consulted, as well as to discuss the survey outcomes and study limitations.

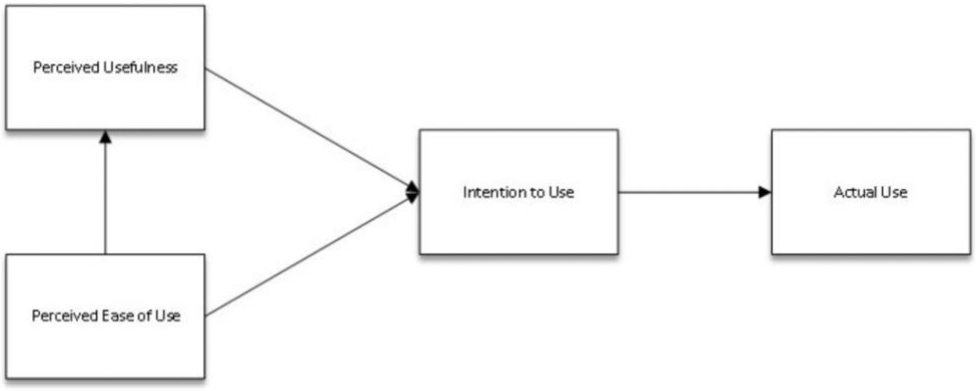
7.2.1 The Technology Acceptance Model

When it comes to specific studies on wound monitoring and their acceptance, literature does not provide sufficient information, despite studies for the overall healthcare sector (Yang, et al. 2016, Ketikidis, et al. 2012, Pai and Huang 2011, Holden and Karsh 2010). Also, there have

been studies on acceptance regarding (smart) wearable devices (Yang, et al. 2016, Li, Chan and Man 2019), and on the relationship with the perceived usefulness of the technology in potential disaster situations, which has been shown to be influenced by the current perceived usefulness of a technological device (Cheng & Mitomo 2017).

To analyze the study, the **Technology Acceptance Model** by Davis (1989) has been used. Its main arguments are that the intention of an individual to adapt technology in general, **(intention to use)** refers to the idea that the individual both, aims to utilize the technology and would recommend it to others. It is influenced by **perceived usefulness** and **perceived ease of use**, while perceived usefulness can also be impacted by perceived ease of use. These factors are shown to have an impact on the perception of the technology, thus the overall acceptance (intention to use), which will have an impact on the actual utilization of the technology (Ajibade 2018). A visualization of the Technology Acceptance Model is shown in figure 3 below.

Figure 1: Technology Acceptance Model



For conducting the survey, different variables are considered to test people's readiness for the digital bandage. These are going to be described in the following.

7.2.1.1 Perceived ease of use and perceived usefulness of a digital bandage

The **perceived usefulness** describes the degree to which someone believes technology increases their job performance (Davis 1989). In regard to vulnusMON, this could mean that the data made available to medical staff increases the accuracy of the diagnosis and observation of the current state of the wound.

The **perceived ease of use** is the degree to which an individual believes the technology is easy to use (Davis 1989). Specifically healthcare technologies should be user-friendly to have a positive impact on attitudes toward the adoption of them (AlQudah, Al-Emran and Shaalan 2021). Studying the overall acceptance of wearables in the population of over 60 years old, as Li, Ma, Chan & Man (2019) did, results show that the perceived ease of use did not affect the use intention of using a new technological device. The usage of those is overall perceived to be easy. For elderly it is especially important to have new technologies be compatible with existing devices (Ahmad, et al. 2020).

Healthcare professionals perceive personal digital assistants to increase productivity, make the job easier, and increase the quality of care (Liang, Xue and Byrd 2003). Based on the arguments of the previous studies on technologies in healthcare, the hypothesis that **the bandage is perceived to be easy to use** is formed. Though the survey does not target solely working in the medical industry, it is assumed that people overall could have similar perceptions when it comes to vulnusMON. The specific test items are listed in Appendix 5.

7.2.1.2 Perceived cost-effectiveness of a digital bandage

Holden and Karsh (2010) state how the Technology Acceptance Model has to be adapted when applying it to healthcare technologies. The **perceived cost-effectiveness** is a variable that Ahlan and Ahmad (2014) added to the model, while specifically investigating Health Information

Technology (HIT) in developing countries and expanded the framework with variables, that include the "Perceived Cost-effectiveness" (see Appendix 3). The conceptual model shows that medication, transportation, time loss, and productivity are factors impacting the perception of cost-effectiveness in HIT.

One of the main arguments Schulz (2022a) stated in favor of the project, is that medical staff would be able to save time within their schedule. Additionally, patients might be able to return home from the hospitals and would not need to be taken care of, if the digital bandage indicates that the status of the wound is well. Thus, for the purpose of the survey, the **hypothesis is formed that the digital bandage is perceived to be time-saving**. Though perceived-cost effectiveness additionally tests the degree to which participants would agree that the digital bandage could save money, which has also been added to the test items. About 50% of people from the United States state that they had skipped or delayed medical care due to the high costs (Cutler 2020), which could indicate that people from different countries could see the cost-saving factor differently. The statement of testing age and the correlation of country of origin will not be included in the analysis. This has been decided on as most survey participants are expected to come from Germany, due to personal reach, a comparison of people's perceptions from different countries does not make sense.

7.2.1.3 Perceived risks of a digital bandage

Risks or **perceived risks** associated with wearable devices were found to be performance risks when it comes to the **quality of the measurement and privacy concerns** (Li, Chan and Man 2019).

Thus, in the survey, a statement is included that asks the participants about the accuracy of the bandage (Appendix 5). Schulz (2022a) underlines how people could associate risks with them. Specifically, by using and analyzing the data it provides, it is possible that one could be able to

detect information, such as when the utilizer gets up and more. In another example, Schulz (2022b) stated that by monitoring data, assigned doctors and nurses are able to draw further conclusions, such as on smoking habits influencing the speed of how fast the wound heals. Though it has been shown that patients are willing to share their health data for the research (Seltzer, et al. 2019), the question arises whether a patient would be comfortable having that information shared with the medical staff in an unconventional way.

A previous study on smart wearable devices has shown that people who believe that the technology is useful, have **privacy concerns** (Cheng and Mitomo 2017). Though vulnusMON cannot be identified as a classical smart wearable device, and similar studies do not exist on digital bandages, it could indicate potential directions for the perceived risks of vulnusMON. Also, patients' concerns about privacy and data security are shown to be related to "*countries internet infrastructure and security software*" (Carbonaro, Elsaied and Semerci 2021).

For this reason, individuals believe whether the digital bandage would invade their privacy or not and the concern of potential data leaks was included in the survey (Appendix 5). Also, based on the arguments presented above, the hypothesis is made that younger people (18– 25) are not as concerned about potential data leaks as older people.

7.2.2 Measures

The methodology for the conduction of the survey was described in chapter 4. All in all, survey measures included demographic variables (see Appendix 4) of the Technology Acceptance Model (perceived usefulness, perceived ease of use, etc.), and extensions (perceived cost-effectiveness, etc.) of it. The **hypothesis** formed throughout the last chapter are stated below:

H1: The digital bandage is perceived to be easy to use.

H2: The utilization of a digital bandage is perceived to be timesaving.

H3: People aged 18 – 25 have less concerns about potential data leaks than people aged 35 or above.

The survey was divided into two parts: demographics and survey test items. As the survey focuses on the **perception of society on a digital bandage**, the Likert scale is used to measure the survey participant´s understanding and judgment of a specific topic (Joshi, et al. 2015). This was done for the second part of the survey. The survey participants were given five answer possibilities to each statement, ranging from strongly disagree to strongly agree; strongly disagree was allocated a weight of 1, neither disagree nor agree with a 3, and strongly agree with 5.

7.2.3 Survey Outcomes and Discussion

As mentioned, in chapter 4, the survey was open for a total of 4 weeks and was **completed by a total of 111 individuals (n= 111**). The survey was completed by 65% female (n=72), and 33% male (n=37). 2% (n=2) of respondents do not identify themselves either as male or female. 50.45% (n=56) of participants are between 18 and 24 years old, 34.23% (n=38) are between 25-34 years old, 3.6% (n=4) individuals are between 35 and 44 years old, 4.5% (n=5) participants between 45 and 54, 6.31% (n=7) between 55 and 65. 0.9% (n=1) of participants are above 65 years old. With 58.56% of respondents (n=65), most respondents currently are students, followed by 27.03% (n=30) being employed, 10.81% (n=12) self-employed, 0.9% (n=1) public officials, and 2.7% (n=3) unemployed. 92.79% (n=103) of respondents do not work in the medical industry. Visual representations of the responses on demographics can be found in Appendix 6.

To test the hypothesis stated, the survey items PU1 and PR5 (see Appendix 5) have been changed, as they were formulated negatively, so the other way around. For this reason, an “R” has been added to refer to them, as shown in Appendix 7.

Next, as the different items texted have been previously allocated to different variables, it was important to calculate their mean. As an example, PU1 and PU2, belong to perceived usefulness. Considering all people who filled out the survey (n=111), it can be stated that people rather have a neutral standpoint when it comes to the **perceived usefulness** of a digital bandage (mean of 3.04). These values are presented in Appendix 5. Secondly, people overall agree with the answer statements given on the **perceived ease of use** (mean of 4.09). The overall mean for item PEU1 is 3.79 (Appendix 7). Based on this, one can state that **H1, the digital bandage is perceived to be easy to use, is correct.** For vulnusMON, this means that the bandage can be integrated into the daily lives of the patients easily. The digital bandage provides additional information, besides having the protecting function. It could be regarded as an updated version of traditional bandages that are used today.

Perceived cost-effectiveness overall has a mean of 3.85, indicating that people tend to agree with the answer statements provided. To test H2, a look at survey item PCE1 is needed. When it comes to age groups, people aged between 45 and 54 agree with the statement the most, followed by the age cohorts 55-65 and 25-35 (Appendix 9). As the overall mean is 4.09 (Appendix 7), the number indicates that people perceive the digital bandage to be timesaving. Thus, **H2 is correct**, **stating that the digital bandage is perceived to be timesaving.** This result indicates that vulnusMON overall is perceived to save time for individuals, which in turn could lead to more efficiency. Though it has not been indicated, to what party involved (medical staff or patients) the term “timesaving” refers to, overall survey participants do not disagree with the statement. The aspect of timesaving cannot only be applied to nurses and medical staff, due to the reduction of unnecessary in-person visits, but also to the patients, who can leave the hospital earlier and might benefit from a faster healing process of the wound, due to the accuracy of the data.

Perceived risks had a mean of 3.5 (see Appendix 8). As this number is between a neutral answer statement and tending toward agreement, survey participants do associate the project with some risks. The mean of 4 for the **intention to use,** indicates that the people somewhat agree that they would either recommend others wearing the digital bandage, or would wear it themselves. Considering the different age groups, survey participants older than 45 seem to be more concerned about their **privacy** being invaded wearing a digital bandage than younger people (see Appendix 10, test item PR1).

Looking at **potential data leaks** (see Appendix 10, test item PR3), people between 18 and 24 tend to disagree with it, with a mean of 2.86. This number is lower for the age groups 45 – 65. This might indicate that younger people, who tend to have a higher affinity towards technologies, are less concerned about data leaks than people of higher age. As only 8 participants of the survey were older than 55, the sample size is very small, which could mean that the answer statements provided are unreliable. When it comes to the belief of the data provided by the digital bandage is accurate, for the age group of 18- 24, the tendency leans towards agreeing, while for the age groups of 45- 54, somewhat disagrees. This underlines the statement that the **younger age group might have a higher affinity towards technologies** and has more trust when it comes to them. Thus, based on the data available in this survey, **H3 is correct**.

Regarding the **intention to use** the digital bandage, with a mean of 4.25 for survey item IU2, it is clear that the survey participants overall would wear a digital bandage themselves. Yet, they are more reluctant when asked if they would recommend others wearing it (see Appendix 7), which could represent uncertainty.

In general, the outcomes of the survey are similar to the conclusions that have been drawn in prior studies. People generally are willing to apply a digital bandage. As answers given by the age group of 18 – 24-year-olds represent 50.45% of total respondents, the assumptions made by

Carbonaro et al. (2021) about age having an impact on the acceptance levels of technologies, can be underlined by this study. Overall, if the **acceptance rate** of health information technologies would be low, it could lead to **delay or failure of successful implementation** (Ketikidis, et al. 2012)**.** In this case, due to the small amount of people participating in the survey over the age of 55, it cannot be concluded if the success of vulnusMON will be delayed or not. Yet, it is likely, that when the generational cohorts of above 18 get older, and will have increased risks to chronic wounds, they will not accept the technology. The adoption of those technologies can lead to a change in how patients manage their health and participate in care (Smith and Magnani 2019).

7.2.4 Limitations and future studies

The Technology Acceptance Model (Davis 1989) can be argued to be limited, as the acceptance of an individual to use specific technology, can be diminished by "*the company´s rules, policy and IT guidelines*" (Ajibade 2018, 9). In this case, two scenarios must be assured. For one, it must be guaranteed by the vendor of vulnusMON that data is **treated confidentially,** as well as the practitioners and the organizations. Both points have to be communicated to the patients in order to assure that the data collected will remain private. Second, institutions that are looking to implement vulnusMON have to make sure, that their infrastructure is equipped to handle this sort of information.

Considering the fact that, **IT skills** are shown to influence a user's attitude towards the use of technology (Ajibade 2018), due to the high amount of young people answering the survey, the survey is limited in regard to the utilization of a digital bandage today specifically in chronic wound scenarios, as the ratio of people with chronic wounds is higher for the age group of people over 60 (Yao, Niu and Cheng 2020). Thus, it is recommended to study the acceptance of digital bandages specifically with patients diagnosed with chronic wounds. In the case that the acceptance levels are

low, it can be recommended to educate the patients on the purpose of the digital bandage. In order to be able to do so, **doctors and nurses** will have to meet the prerequisite of accepting and utilizing the digital bandage prior. As a digital bandage, such as vulnusMON, will only be applied after a doctor's decision, the priority has to be to first **educate and convince them of the benefits** of such technologies, in order to assure their intention to use is high. It is especially likely that the topic of privacy issues will be one of the most relevant ones. Cheng and Mitomo (2017), as an example, found that people with a high perception of the usefulness of smart wearable technology, view privacy as the biggest issue.

Also, this study focuses on the acceptance of patients. Overall, a study is needed on **people working in healthcare**, specifically with digital bandages and in wound management. Though a study exists on telehealth and wound management, it does not cover the features and possibility of applying digital bandages (Karadag and Sengul 2021). In another study conducted in the Netherlands, having patients fill out a form in an app on their wound status themselves daily, aiming towards alerting doctors on wound problems (Scheper, Derogee, et al. 2019) is closer to the project of vulnusMON. The study showed that perceived ease of use and perceived usefulness were high. This must be tested regarding vulnusMON and be **extended by the intention of use**.

Lastly, the study conducted for the thesis did not focus on factors, such as face-to-face time spent between the medical personnel and patients, as other studies did (Karadag and Sengul 2021). In addition to the perceived-cost effectiveness factor of the reduction of time spent with the personnel, it would be important to understand **how much time spent** exactly with medical staff a digital bandage would decrease. Following that, it would be interesting to understand if a significant decrease in personal interactions would change the attitude toward the digital bandage. For example, it has been shown by Plugmann and Plugmann (2021), that patients do have a desire

for face-to-face interactions and concluded that the problem, with increasing digitalized and automated solutions in healthcare, could potentially be solved by Artificial Intelligence.

8 Discussion – Group part

The important challenges and obstacles for vulnusMON encountered in the chapters above undoubtedly give reasons for a thorough **discussion** concerning a digital bandage. Thus, this chapter is devoted to elaborating on certain aspects and limitations, including a **future outlook**.

8.1 Strengths and opportunities of vulnusMON

As already stated above, the most striking strength of vulnusMON is the **increased efficiency** within the healthcare sector. Especially for the ambulant use case, the mobile nursing service would save time and could allocate resources in a more productive way. If the wound of one patient is healing well and the bandage does not need to be exchanged, the visit can be postponed and vice versa: If the parameters of a wound suggest a worsening of the overall patient's health status, a visit outside of the regular schedule could be held. Since the overall healthcare system is expected to shift from hospital-centered to **home-centered** by 2030 (Rahmani, et al. 2017), this demonstrates vulnusMON's **relevance** in today's healthcare system.

Additionally, there is an **increase in the accuracy** of the treatment since the data is always collected by the same sensor. In medicine, multiple errors occur due **to human mistakes**, such as rash testing or wrongful diagnostics at the wrong time. A study from the US National Academy of Medicine demonstrated that diagnostic errors are to be seen as number one in a Top Ten list of patient safety concerns (PDD 2018). It is in human nature to make mistakes, but with the sensors in the digital bandage, the measuring is less likely to be wrong. This not only allows a better

comparison between the various stages of wound healing and to see if the healing process is advancing as planned, but it also allows for analysis that goes beyond that.

The latter is a fact that should not be underestimated towards future development: The idea of vulnusMON provides enormous possibilities for **further data exploitation** in the medical context. Evidently, this implies compliance with data security and privacy as well as the patient's consent. However, it is a huge asset for vulnusMON in the foreseeable future and a potential market expansion will follow in chapter 8.6.

On the same note, the problems concerning the staff shortage in healthcare and the circumstances in the work sphere have already been mentioned in chapter 2. Although society is united on the need for drastic change, very little has been done in practice because the consensus usually breaks down as soon as initiatives get specific enough to be implemented. It is for digital innovations such as vulnusMON that not only the **reputation of the industry can be enhanced** and step back from its rather rusty image towards a technology-driven industry that will attract more applicants, but more importantly, ease the conditions for both the stationary as well as the ambulant scenario, pushing the tasks of the practitioner in healthcare back to the center of their doings, keeping their motivation high and decreasing frustration.

Thus, it is stressed that **digitalization in healthcare is not an enemy of the staff** – it neither should nor is able to replace the workforce. Rather, it shall **give support**, expand the skills of employees, and counteract a shortage of skilled workers in the care sector.

8.2 Generational cohorts

Since vulnusMON focuses on treating chronic wounds and bedridden patients, many of them are prospected to be **elderly** (Schulz 2022a). This generation is known to be more restrained towards digitalized tools, underlined in chapter 7. Thus, vulnusMON should focus on gaining trust

and ensuring adequate handling to eliminate risks of both, general reluctance, and potential misconduct.

Another aspect that should not be neglected is the risk of **isolation**. Meristö and Laitinen conducted a study in 2020, delving deeply into the challenges for elderly people caused by expanded digitalization. As demonstrated, digitalization and AI in healthcare can only work with human support, and vice versa. While the implementation of digital tools such as vulnunsMON is a key instrument to a more efficient economy of time for healthcare workers, it is in human's desire to long for **social contacts**. Given the ambulant scenario, an implementation of vulnusMON might mean that healthcare workers will not see patients at home on the same regular basis, since there is no need to do so from a medical perspective. Usually, such visits are held on the same schedule, however, with vulnusMON, if it is evident that the bandage does not require to be exchanged, the nurse might not come. A better number of elderly people in home care often rely on their physicians as social contacts since they might not be able to participate in social gatherings elsewhere. Even though the implementation of vulnusMON would not mean a cessation of these visits; however, the regularity among them is to decrease. Especially for older generations, having a steady routine is essential and a disruption thereof could agitate their familiar setting. All that might bring discomfort for the patients, leading to **loneliness and social isolation** (Meristö and Laitinen 2020).

On that note, elderly people are often **afraid of being left alone with digitalized tools** since their knowledge and trust are not profound enough to make them feel safe. On the contrary, younger relatives of elderly people often feel more secure in the knowledge of a digitalized tool supporting their relatives when they are not around. In literature, this trend is often referred to as the "*digital orphans*" (Lahtiranta 2014). Nowadays, especially for generations Y and Z, digitalization and AI have become a fundamental part of their daily life, eliminating the fear of encounters. For older generations, however, skepticism, mistrust, or even refusal may emerge.

Regarding vulnusMON, the permanent monitoring might make them feel insecure, as far as that they feel they are **losing the feeling of comfort** within their own home by being steadily monitored. Constantly depending on somebody else's help concerning the bandage runs the risk of diminishing their autonomy. This is enhanced by the fact that in cases of little knowledge, the patients do not even know **when to ask for help** since they cannot recognize complications (Meristö and Laitinen 2020), such as when the bandage slips out of position. This stresses the importance of having vulnusMON thoroughly explained to the patients.

In contrast, as demonstrated in the survey, younger generations are very likely to utilize mobile devices. The smartphone is the device that is mainly used in order to learn about health (Rich, et al. 2020). As younger people grow older and eventually get to the age at which chronic wounds are more likely to occur, it could potentially lead to **a greater adoption and acceptance rate of** vulnusMON in the future. Nonetheless, more technological solutions will enter the market in the meantime. That is why, now, one cannot predict whether there will be different solutions in a few years for similar approaches and vulnusMON, as it is today, could be endangered by the fast-moving nature of digitalized solutions. That is why it is of high importance to continuously **stay UpToDate** with current technological trends, to diminish the risk of becoming obsolete.

8.3 Challenges for vulnusMON

8.3.1 Organizational Burden

When integrating health tools, challenges can be faced due to the complexity of healthcare systems. These include training, IT integration, information security, human capital investments, and adapting existing real-world workflows (Marwaha, et al. 2022). Considering **training,** especially the training of the staff is necessary (Schulz 2022a): To thoroughly understand the way the bandage works is essential to achieving the promised efficiency. This is a cost and time factor

that arises when the technology is adopted and needs to be considered and planned before implementing the project.

On a similar note, when integrating vulnusMON in hospital settings, as an example, the information provided by the digital bandage could automatically be added to digital patient files and increase the efficiency of overseeing the healing process. Yet, this can be linked to risks such as privacy issues and high technological pretenses as discussed in chapter 5.

8.3.2 Administrative Burden

Since digitalization has become such an omnipresent element of our daily lives, certain **legislative and ethical regulations** have been put into place that are of high relevance for vulnusMON: In the European Union, the Charter of Fundamental Rights, specifically states in Article 8 that people have the **right of protection of their personal data** (EUR-Lex 2012).

Furthermore, in 2021, the **Patient Data Protection Act** (Patientendaten-Schutz-Gesetz, short: PDSG) entered into force in Germany, introducing new requirements for the handling with patient information in electronic format, applying to healthcare institutions that handle sensitive data. Among other regulations, it states that all healthcare institutions, regardless of their size, are to take precautions to have thorough security for patients' data, including protection for their networks and not storing sensitive data locally if it is not essentially required to do so. Germany's Federal Commissioner for Data Protection and Freedom of Information has indicated that this does not exclude them to also obey towards the **General Data Protection Regulation (GDPR**), in which the European Data Protection Regulation has strengthened the rights in handling patient data, which became effective in 2018 (Coos 2021, Efthymiadou 2022).

Likewise, recently **laws** have been passed that give doctors the possibility to **prescribe digital health solutions** (strategy& n.d.). While Germany is not as digitally advanced as other countries

in Europe, due to the lack of deployment of digital tools in the past years, now different initiatives are in discussion for the deployment of digital solutions. However, it is yet uncertain when these will become effective (Hawkins 2021).

To eliminate legislative obstacles, vulnusMON should not only focus on **elaborate security measures** that have been presented in chapter 5, but also **align with legal implementations**. This includes ensuring juridical and ethical compliance with the digital structure of the respective hospitals that are to work with vulnusMON.

8.4 Costs

8.4.1 Production costs

First and foremost, the production costs of the bandage have already been touched upon in chapter 6. Additionally, the budget has to incorporate the development of the algorithms, the app and the overall technological accessibility. For this, a solid financial business plan needs to be established, however, this does not lie within the scope of this work. More so, this chapter provides an overview of matters related to costs that ought to be regarded.

8.4.2 Investments in digitalization of the healthcare industry

On another note, undoubtedly, the implementation of vulnusMON requires **financing**. In general, investments in hospitals and other healthcare institutions remain a challenge in Germany. Additional sources of financing need to be tapped as there is a heterogenous digital infrastructure: **Access to the capital market** is only available for a few, usually private hospital companies (Glauner, Plugmann and Lerzynski 2021). Overall, it can be stated that transformations of any kind, notably digital transformation, are somewhat of a challenge to push through in Germany. The country ranks penultimate place in the Digital Health Index Ranking (Bertelmannsstiftung 2022). As for all digitalization projects, vulnusMON is in need of proper **investments**, and being

successfully implemented in hospitals might constitute obstacles. While this does not affect vulnusMON as a project, rather, it may compromise the success of implementing the digital bandage within healthcare systems due to a lack of financial investments overall.

8.4.3 Decreasing healthcare costs

On the contrary, with vulnusMON, general costs in healthcare may be **reduced** in a sustained manner. By optimizing the routes of healthcare workers in the ambulant use case, longer working hours that must be paid can be eliminated. Related, it specifically **saves labor costs**, as the scheduling of the nurses is much more efficient and accurate in the stationary use case. Furthermore, eliminating waste could not only have environmental benefits as discussed in chapter 6, but also help to reduce the financial impact and to allow health systems rebounding to become more affordable (Gebreyes and Lambdin 2021). By reusing half of the patch, vulnusMON's stakeholders will be able to decrease their **own spendings** and cutting costs in production (Schulz 2022c).

In general, digitalization will mark its impact within the healthcare sector by additionally impacting the supply chain and supporting more transparent communication and ongoing monitoring. The collected data and its predictive forecasts lead to a more **cost-efficient inventory** and drive preventative care as well (Phalange 2017).

8.5 Supply Chain and Resource Shortage

8.5.1 Dependency on the Supply Chain

Another factor that needs to be evaluated is the **dependency** on solely one or a handful of suppliers throughout the production process. As already mentioned in chapter 6.2, there are limited amounts of potential production sides which the stakeholders of vulnusMON would have access to. If one part of the supply chain collapses or a problem occurs within the procurement process,

the entire production must be paused and, temporarily, no goods can be produced. The resulting reliance on solely one producer implies a potential risk for a steady delivering capacity.

Since the producer might be aware of that monopoly position, he has the upper hand in their working relationship: In case of price adjustments, for example, vulnusMON is forced to accept all demands, for the lack of alternatives. Additionally, **disturbances such as geopolitical tensions** or **environmental disasters** support the dependency within the supply chain. A further explanation can be found in chapters 6.2 and 6.3.

Thus, to increase independency and ensure a thorough success, at least a second supplier needs to be acquired to protect vulnusMON from sole decision-making power on behalf of their supplier and other potential risks of force majeure.

8.5.2 Resource shortage

Related, faced with various environmental factors, vulnusMON may countenance potential threats such as the current **chip shortage**, which may interfere with a successful implementation. Chips are essential for processing the measured data as well as transferring them. A shortage thereof also threatens the production of life-saving medical devices and systems. They are used in various devices, also providing real-time data, such as the increasing number of chronic diseases. Therefore, initiatives have been formed, aiming to allocate chips by priority areas (World Economic Forum 2022), being uncertain as to when it will come to an end. Other companies are forming joint ventures in countries such as India and Malaysia, to increase the chances for a guaranteed production volume (Hoecker, et al. 2022). The stakeholders of vulnusMON need to be aware of this exposure and incorporate a **prescient production plan.**

8.6 Market expansion

8.6.1 Expansion to other countries

Different environmental factors represent an opportunity for stakeholders of vulnusMON to enter new markets. First and foremost, an expansion to other markets in different countries proves potential: A patient-oriented system allows flexibility in regard to time and location for delivering healthcare (Mamyrbekova, et al. 2020). The World Health Organization (2021) presents objectives that aim to create a **global strategy in digital health:** The goals for 2020 – 2025 include the sharing and the exchange of best practices and technologies cross.

However, countries have different healthcare systems, which leads to different **health insurance structures**. Since an implementation of vulnusMON requires a thorough understanding and accordance to, e.g., rates of remuneration of health insurance, it is of utmost importance to thoroughly study the according way to approach certain markets, potentially with the help of local institutions that are familiar with the process. In some countries, among them Germany, health insurance is mandatory. When it comes to hospitals, around half of the available beds remain in public hospitals. Yet, the number of beds in for-profit hospitals has been growing (The Commonwealth Fund 2020a). In comparison, in the United States, most people that have health insurance are covered through private healthcare, while the uninsured rate of the population was 8.5% in 2020 (The Commonwealth Fund 2020b). The US healthcare system is rather expensive, perceived by many to be unfair, and being accessed the least. Yet, the number of people with diabetes and obesity is very high (Thomas n.d.), marking a good standing for vulnusMON: Chronic wounds have been shown to heal differently for patients who have diabetes and since wound healing process is often delayed, high costs are associated with them (Jude and Blakytny 2006).

On that note, **expansion to other markets** relies not only on accordance to healthcare systems but also demands for a thorough understanding of local compliances and laws. Given the example above, in contrast to the already mentioned GDPR in Europe, in the United States exists no general law that covers all kinds of data. Instead, different acts and laws, specific to different sectors and individuals, exist (Klosowski 2021). The **Health Insurance Portability and Accountability Act (HIPAA)**, represents a standard for treating and collecting health information on patients (Centers for Disease Control and Prevention n.d.). Since the security of data is of utmost importance when implementing vulnusMON as discussed in chapter 5.2, this remains a challenge for an expansion to other markets.

Likewise, as demonstrated in the survey and the analysis of outcomes in chapter 7, it is evident that people from other countries have **different perceptions** of the digital bandage and thus, may perceive its use differently. When entering new markets, it must be assured that society's perceptiveness has been considered and adapted to local standards and possibilities.

That being said, if all matters are examined, vulnusMON could potentially benefit from an **early-mover advantage**. Typically, first-movers for technologies can gain an advantage through a learning curve, where costs decrease while output increases. Second, a first-mover advantage can derive from succeeding in patent applications and being one of the first ones there (Liebermann and Montgomery 1988).

8.6.2 Portfolio extension

As of today, vulnusMON’s value proposition is to provide it to bedridden patients specifically with chronic wounds (Schulz 2022a), and thus, is targeted towards a niche that continues to grow. As it has been found, not many solutions like it exist on the market today. An idea for the future scalability of the firm working on the project vulnusMON would be to **extend**

the offer by implementing the established technology on other types of wounds, specifically acute wounds, such as measuring the healing of the scar in postoperative scenarios. As the objectives, of simplifying the way healthcare is delivered, remain the same, this approach can be considered a product line extension (Kim, Min and Chaiy 2015). As previously mentioned, digital wound monitoring solutions already exist today (Scheper, Derogee, et al. 2019, Gunter, et al. 2018), however, it still shows high unexploited potential, especially considering solutions like bandages.

It goes without saying that other types of wounds require different healing standards and thus, might depend upon other parameters that need to be measured, obliging for a new or extended assembly of sensors. Likewise, since these patients may not be bedridden and be mobile, this needs to be considered and must be squared with the proposals given in chapters 5 and 6 concerning data transfer and assembly of the bandage such as battery supply.

8.7 Sales, Marketing and Distribution

As already mentioned in 8.4, the freely available budget for the healthcare sector is limited by a small amount. Therefore, conducting marketing research for proper successful marketing is very restricted. Most organizations **solely invest one to two percent** of the total revenue and do not have an individual department within the organizational structure for either marketing or conducting research. By outsourcing and reporting to a third party, biases are minimized, and the confidentiality of the study will be secured. Hereby demand can be forecasted independently as well as the acceptance of certain innovations and implementations (Kotler, Shalowitz and Stevens 2008, 15).

Before conducting relevant research, stakeholders of vulnusMON need to decide whether the product should be marketed as an innovative **digital product** or a **classical bandage**, which is a decision that sets the path for further marketing strategies. Since vulnusMON’s value proposition

is mainly based on the gained efficiency due to digitalization, for this paper, it is decided to be targeted as a **digital product**. However, first and foremost, it is important to understand the healthcare industry and the according ecosystem of vulnusMON. The complex architecture demands for a thorough understanding of the relationship structure: There are not only the consumer, but also providers, payers (e.g., insurance), suppliers, and policymakers (Agarwal, et al. 2020). All these players insist on different individually targeted strategies to be marketed to.

This complexity is exacerbated by multiple laws and regulations in the medical industry, e.g., health insurance catalogues. It is for these reasons that, despite the decision to be distributed as a digital product, stakeholders of vulnusMON should rely on existing distribution channels to ensure smooth operations. Due to L&R's standing within the industry, stakeholders of vulnusMON should try to negotiate to incorporate the project within their existing distribution channels, since they are familiar with the process and have existing distribution partners, facilitating the process.

Nonetheless, if a cooperation with L&R won't take place, or either way, **key strategic channels** for marketing and distributing need to be defined. For one, medical expertise and wound centers in Germany are independent service providers where several ambulatory physicians work together cooperatively. In contrast to local medical centers or individual medical practice owners, the centers differ in size and are characterized by an organizational separation of the ownership from the medical treatment activity (Medizinische Versorgungszentren 2021). If a cooperation was to be entered, vulnusMON would benefit by **accelerating** the distribution process since a lot of different practices are integrated in the centers, making it easier to spread the product. Likewise, **local medical-care centers** or general practitioners should be targeted, combining all local family doctors in a defined location, as well as large caregivers, e.g., Caritas ambulatory services or Home Instead GmbH (Schulz 2022a). Caregiving organizations take care of more than 1.6 million

ambulatory patients in Germany (Borchert 2020), thus, without a doubt, it is important to gain these medical institutions.

Regardless of the distribution channel and the approached way, attention needs to be paid to how to market vulnusMON. For this, Agarwal, et al. (2020) discussed digital transformation in healthcare marketing, proposing a value-centered marketing framework to quantify value creation. In the case of vulnusMON, that means to simplify the caregivers' work and demonstrate the resulting **relief, and not as a substitution.** It will reform the workflow of the nurse and give them the opportunity to revolutionize the classical role of a nurse by becoming part of a digital innovation by introducing a new role of Digital Bandage Manager. As already mentioned, the role of a nurse will rather shift the tasks of a nurse back to a medical focus, instead of making it obsolete which needs to be stressed (Corbin, Kelley and Schwartz 2001).

8.8 Future Outlook and Implications

As it has been encountered in the chapters above, Germany remains rather **reluctant towards digitalized innovations**, enhanced by the overall situation when it comes to digitalizing healthcare in the country: Not only do laws and regulations tend to be stricter than in other countries, but also digitalization has not been promoted as much as it has been in other countries. All these reasons raise the question if vulnusMON should first be developed in a country that is **more advanced** when it comes to digitalization in healthcare.

Thus, it is recommended to enter a country with a strong economy and in which the insurance system is similar to the German system, but only after successful project implementation in Germany, Nordic countries utilize technologies in the public sector. In general, these countries aim to build strong foundations for digitalization networks, skills, and education (Larsen n.d.). When it comes to the overall healthcare system, the Nordics tend to adopt new technologies early

and the healthcare system can be described to be of high quality (Bergman, et al. 2018). Within the health tech community, cooperation with other companies is engaged, by the initiative HealthTech Nordic, which is the largest community for health tech companies (HealthTech Nordic 2022).

Denmark's 4G coverage in 2020 was above the EU average and internet usage by citizens in Sweden was ranked highest in the same year (Ruengchinda 2020), indicating the advancements in technology available in those countries. The high living standard, as well as the free healthcare system, enable companies to enter the market (Bradfordjacobs n.d.). The country especially focuses on enabling health tech startups to test and bring their solutions to the market. The main missions of the healthcare industry are to improve the treatment of chronic conditions, make the population healthier, and increase digitalization (DI Life Science n.d.). Many corporations between private and public stakeholders exist (Digital Hub Denmark n.d.).

Given this, it would be interesting for vulnusMON to conduct some research on potential market entry strategies in this country, assuming it succeeds in Germany. Especially considering free healthcare systems in countries such as Denmark, there are some parallels with Germany, which could simplify research and market entry measures. After all, it is advised to build and test the prototype in Germany and after a successful implementation to expand distribution-wise to different countries. It is recommended to consider the Nordics, such as the Danish market as its advantages just have been displayed.

9 Conclusion – Group part

The healthcare industry is constantly facing challenges, such as medical staff shortages and overall bad working conditions that influence the quality of the way healthcare is provided. However, in recent years, a turnaround has been rising to the surface: The increasing implementation of digitalized tools **revolutionizes the sector,** shaping it into a more efficient

ecosystem. On a surface level, all these tools mean an increase of efficiency for the whole industry. At a closer look, however, all these enhancements can only work if they are implemented well, not only within the institutions but also among society.

The purpose of this paper was to understand the digital wound monitoring market, to make a **profound decision** on whether the project **vulnusMON** should be fulfilled or not. It represents an interesting opportunity for the **disruption of the way healthcare is delivered**. Gains in efficiency by easing the conditions for healthcare workers on the one hand and allowing for more precise treatment for the patients on the other hand, create opportunities for an overall enhanced experience in healthcare.

Nonetheless, it goes without saying that the implementation of such a project can face **multiple burdens.** For one, due to the vulnerability of the data being transmitted, reliable data transfer, as well as data security, are imperative. To combat this, various technical solutions have been proposed to ensure a steady data transmission while minimizing the risk of data leaks, deciding for BLE and LTE-M. An obstacle that remains is that of choosing the right algorithm: To be effective, involving not only programmers but also healthcare workers in the design, development, and implementation of AI-based tools is imperative.

Furthermore, wireless data transfer was proposed for the composition of the bandage, with one reusable and one disposable part. Regarding sustainability, vulnusMON shows potential to have a positive impact on reducing not only waste, but also time and cost in healthcare, if all matters are applied thoroughly, and emerging electronic waste is disposed correctly. Similarly, the enhanced allocation of medical staff and their working hours may lead to a positive contribution to the reduction of CO2 emissions.

Following, vulnusMON can only achieve promising success if it is mutually accepted among healthcare workers and patients. However, when it comes to the acceptance of similar

projects, literature is not extensive. Thus, this paper provides a basis for future studies to understand society's perceptiveness. Different generational cohorts might have a different awareness about this, alongside the difference in the perception between medical staff and potential patients which emphasizes the need to be researched.

Regarding all the above, **vulnusMON shows great potential** to enhance the healthcare sector, by increasing efficiency and shedding new light on the rather rusty image of the healthcare industry and **should be further pursued**. Yet, as it has been discussed in the previous chapter, Germany is prone to lagging when it comes to the implementation of digitalization, raising the question of whether it is the right market for such a product. This requires further research and should be implemented by the stakeholders of vulnusMON in the foreseeable future.

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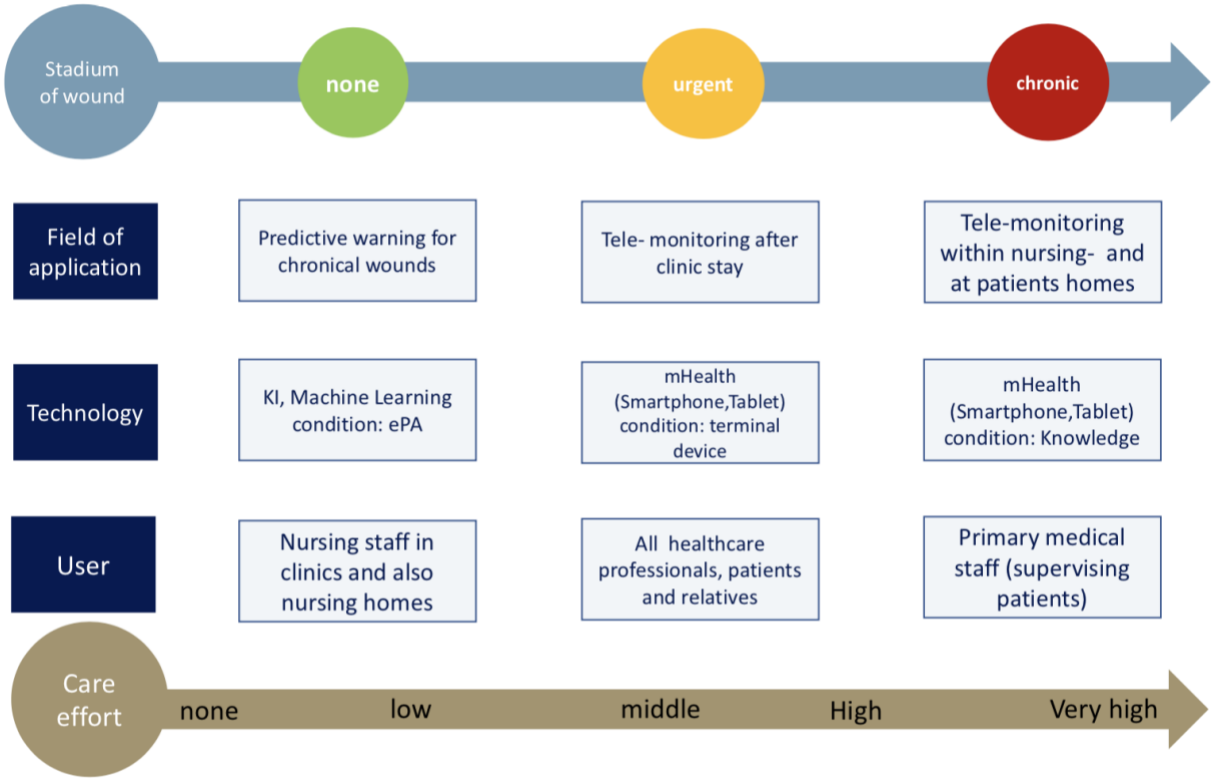
Appendix

Appendix 1

Figure 2: Overview of application fields (Koebe 2022)



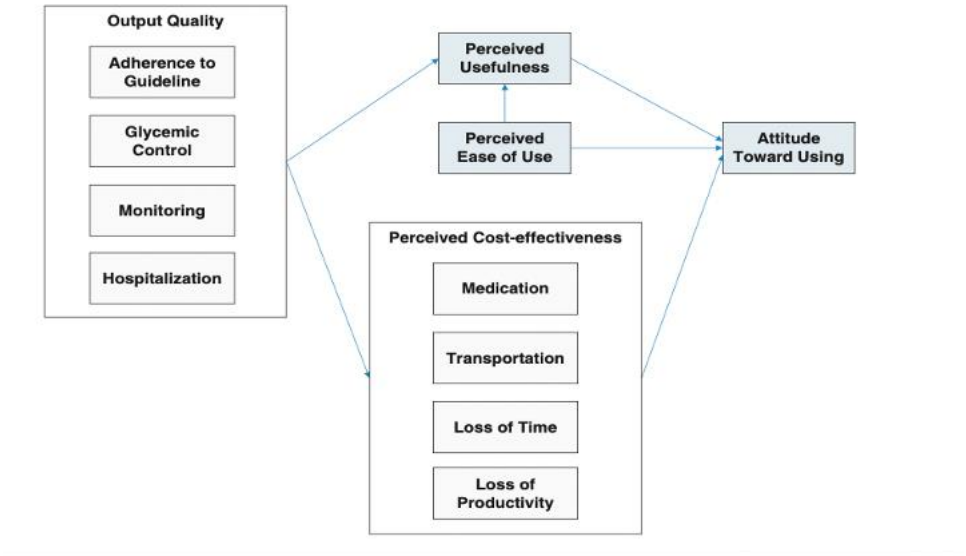
Appendix 2

Table 1: IoT-Cloud provider in comparison

Name of Cloud	**Provider**	**Pros**	**Cons**
MS Azure	Microsoft	Strong focus on Security, multi-level protection. Dependent on external factors. Easily integrated in other applications from Microsoft	Potential of data transfer fees. Technical support rather low.
Amazon Web Services (AWS)	Amazon	Cost-effective. Highly available world-wide. Scalable.	Security limitations. Dependent on Amazon. No technical support. High price variations.
Google Cloud	Google	SSL certificates are automatically renewed. Many storage regions. Strong data analytics. Open source integration.	Complex transition away from platform to other vendor. Fewer global data centers.

Appendix 3

Figure 3: HIT: Acceptance in Developing Countries (Ahlan & Ahmad 2014, 1290)



Appendix 4

Table 2: Survey: Questions (Demographics)

Number	**Question**	**Answer Possibilities**
1	What is your gender	Female Male Other
2	How old are you?	Under 18 18-24 25-34 35-44 45-54 55-64 65+
3	What is your country of residence?	Open question
4	What is your highest educational degree?	No degree High school diploma Academic Degree (Bachelor, Master, Doctoral, etc.)
5	What is your occupation?	Student Employee Self-employed Public Official Unemployed
6	Do you work in the medical industry?	Yes No

Appendix 5

Table 3: Survey Test Items

Variables	**Item**	**Measurement items**
Perceived Usefulness (Davis 1989; Li, Ma, Chan & Man 2019)	PU1	I believe that wearing a digital bandage does not require great effort for me.
	PU2	I believe wearing a digital bandage is easy
Perceived Ease of Use (Davis 1989)	PEU1	I believe digital bandages are easy to use.
	PEU2	I would wear a digital bandage if needed.
Perceived Cost Effectiveness (Ahlan & Ahmad 2014; Schulz 2022a)	PCE1	I believe by wearing a digital bandage, I can save time.
	PCE2	I believe wearing a digital bandage reduces the time spent with medical staff.
	PCE3	I believe wearing a digital bandage is cost saving.
Perceived Risks (Li et al. 2019; Schulz 2022a; Schulz 2022b)	PR1	I believe that wearing a digital bandage increases the risk of my privacy being invaded.
	PR2	I believe the information shared through the digital bandage is very sensitive and should be treated confidentially.
	PR3	I am concerned about potential data leaks
	PR4	I believe that I am in the position to share information I believe is crucial for successful wound healing to medical staff myself.
	PR5	I believe the information provided by the bandage is not accurate.
Intention to Use (Davis 1989)	IU1	I would recommend others to wear a digital bandage.
	IU2	I would wear a digital bandage myself.

Appendix 6

Figure 4: Survey Responses - Gender

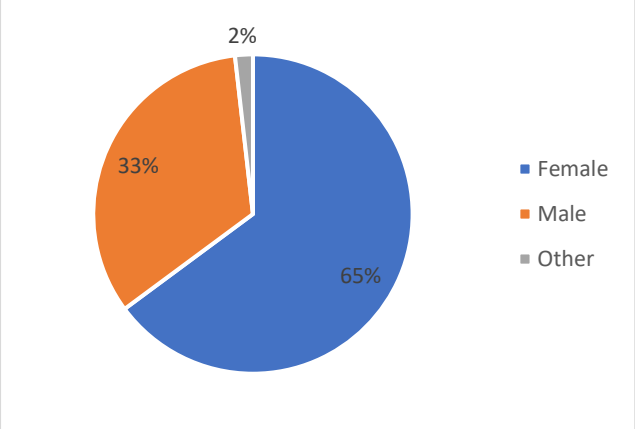


Figure 5: Survey Responses - Age

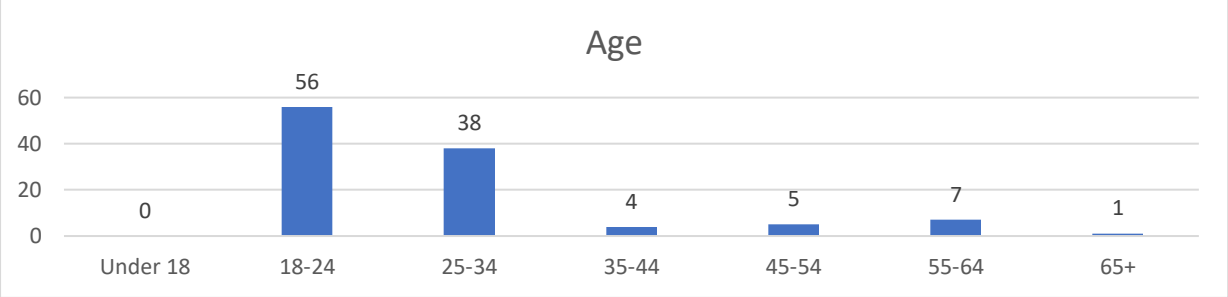


Figure 6: Survey Responses - Education

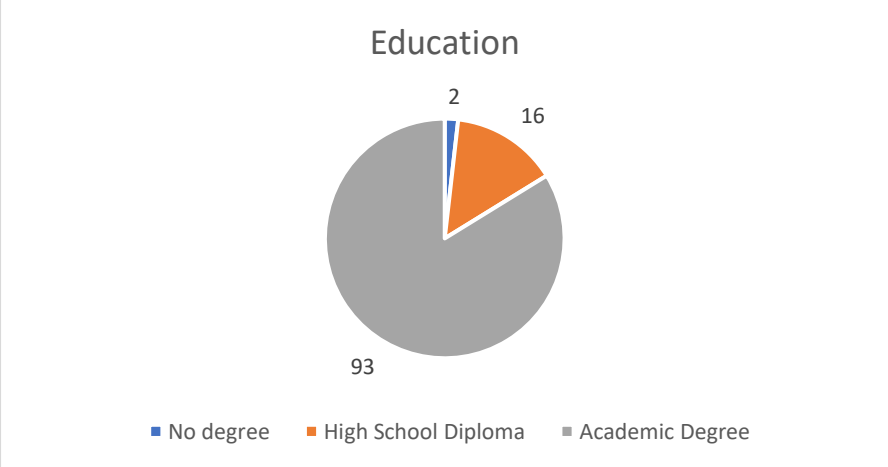
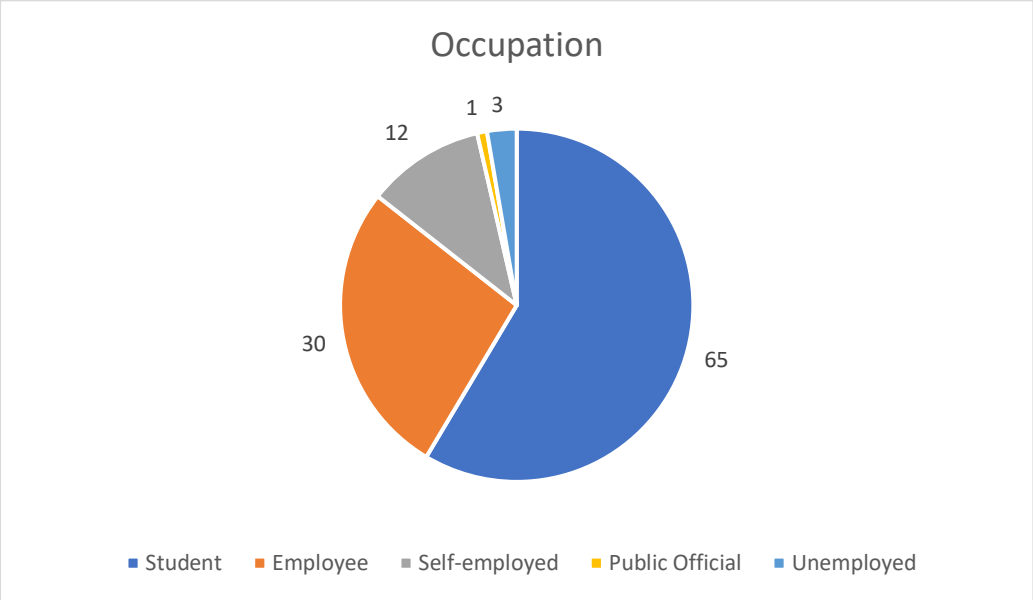


Figure 7: Survey Responses - Occupation



Appendix 7

Table 4: Survey Descriptives

Item	PU1 R	PU2	PEU1	PEU2	PCE1	PCE2	PCE3	PR1	PR2	PR3	PR4	PR5 R	IU1	IU2
N	111	111	111	111	111	111	111	111	111	111	111	111	111	111
Mean	1.98	4.09	3.79	4.39	4.09	4.25	3.22	2.98	4.32	3.03	3.62	3.57	3.57	4.25
Median	2.00	4.00	4.00	5.00	4.00	4.00	3.00	3.00	5.00	3.00	4.00	4.00	4.00	4.00
Standard deviation	1.05	0.880	0.926	0.765	0.977	0.899	1.06	1.16	0.865	1.21	0.963	0.859	0.838	0.858
Minimum	1.00	2.00	2.00	2.00	1.00	1.00	1.00	1.00	2.00	1.00	1.00	1.00	1.00	1.00
Maximum	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00

Appendix 8

Table 5: Survey items grouped

	Perceived Usefulness	Perceived Ease of Use	Perceived Cost Effectiveness	Perceived Risks	Intention to Use
N	111	111	111	111	111
Mean	3.04	4.09	3.85	3.50	3.91
Median	3.00	4.00	4.00	3.40	4.00
Standard deviation	0.419	0.692	0.731	0.528	0.784
Minimum	2.00	2.00	1.33	1.80	1.50
Maximum	4.50	5.00	5.00	4.60	5.00

Appendix 9

Table 6: Perception of time-saving according to age groups

		Age	PCE1
Mean	18-24		4.04
		25-34	4.16
		35-44	3.75
		45-54	4.40
		55 - 65	4.29
		65+	3.00

Appendix 10

Table 7: Age groups and perceived risks

Descriptives

	E	PR1	PR2	PR4	PR5 R	PR3
Mean	18-24	2.86	4.25	3.63	3.66	2.86
	25-34	3.08	4.32	3.63	3.42	3.11
	35-44	2.50	4.25	2.75	3.25	3.00
	55 - 65	3.57	4.43	3.57	3.71	3.43
	45-54	3.40	5.00	4.40	3.60	4.00
	65+	2.00	5.00	3.00	4.00	2.00

Appendix 11

Table 8: Perceived ease of use according to age group

	Age	PEU1
Mean	18-24	3.66
	25-34	3.82
	35-44	4.25
	45-54	4.00
	55 - 65	4.29
	65+	4.00