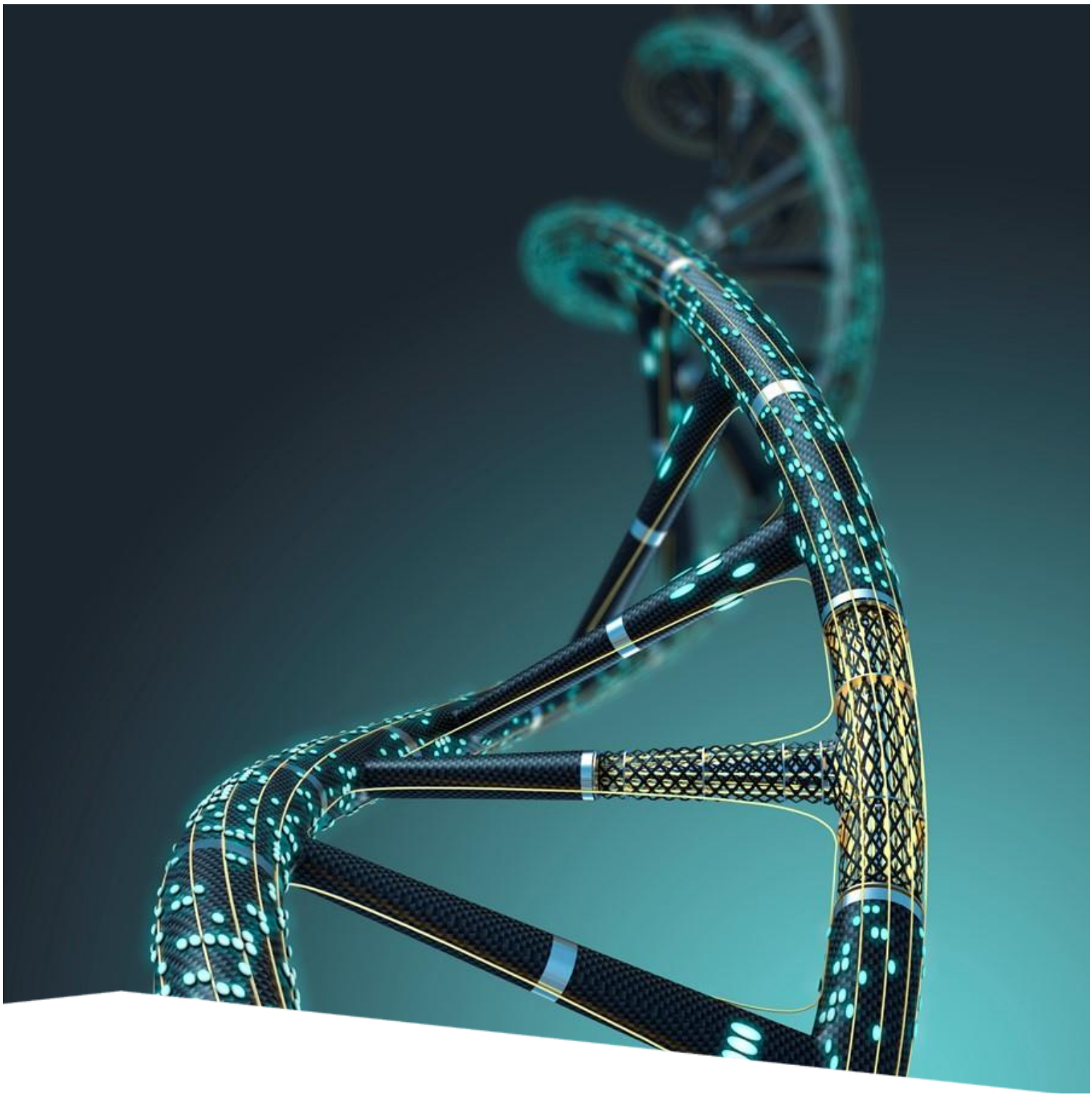

The Ecosystem for Healthcare Robotics in Southern Denmark

Region Syddanmark

DANISH TECHNOLOGICAL INSTITUTE

The Ecosystem for Healthcare Robotics in Southern Denmark

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April 2023

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Table of Contents

1. Summary

- Southern Denmark has a unique international position of strength within healthcare robotics. This is due to the many manufacturing companies and organisations that are located in, and contribute to, Southern Denmark's technology ecosystem.

- However, there is a need to continue to strengthen the conditions for this ecosystem of healthcare robotics, as the healthcare sector currently lacks resources, and this need is only expected to grow in the future. Robots are expected to contribute to the healthcare sector by performing a range of functions that free up existing personnel resources for other tasks, as well as by improving the quality of specific treatments and creating better working conditions for employees.

- This report analyses the Southern Danish ecosystem for healthcare robotics, which includes an analysis of the ecosystem's stakeholders and their relationships, as well as the existing strengths and development potential of the ecosystem. The report then presents eight initiatives that can strengthen different aspects of the ecosystem. The report concludes with some reflections on how the initiatives can be combined into an overall vision for the ecosystem.

- The analysis and initiatives are based on 26 qualitative interviews and two workshops with stakeholders in and around the Southern Danish ecosystem for healthcare robotics, conducted in January and February 2023 by consultants from the Danish Technological Institute.

- Six strengths were identified in the ecosystem: 1. the industrial robotics business environment, 2. relevant education, 3. the strong and open network, 4. the research environment, 5. the "Odense Robot City" brand, and 6. the presence of individual enthusiastic investors.

- Six development potentials were identified for the ecosystem: 1. challenges with scaling robotics solutions, 2. the need for stronger dialogue between clinical needs and technological solutions, 3. the need for greater emphasis on commercial considerations in development projects, 4. challenges with fleet management and integration of different robot systems, due to the different IT systems used by suppliers, 5. the need to ensure continued external input for the ecosystem, so that it is continually supplied with new resources, and 6. a lack of clarity on testing and documentation requirements for healthcare robotics.

- To address these development potentials and strengthen the ecosystem, eight initiatives were identified. These initiatives involve 1. research and development funding, 2. establishment of an international testing environment, 3. counselling for businesses

on the healthcare sector and business cases, 4. open IT standards, 5. establishment of a technology forum, 6. counselling on CE certification, 7. focus on commercial scaling in development projects, and 8. promotion of "Odense Robot City."

- Some of these initiatives can be combined into an overall vision for the ecosystem, which can truly mark Southern Denmark as an international centre for healthcare robotics. This vision is centred around the establishment of an international testing environment, where Danish and international companies and hospitals can test new robot technologies and obtain documentation for their effectiveness in a realistic setting. The testing environment could also be a resource for research and educational institutions that could benefit from the facilities. Pursuing this broader vision will require extensive resources and strategic will but, if successful, it will also establish a unique international healthcare and technological environment.

2. Introduction

Southern Denmark holds a unique position within healthcare robotics. Southern Denmark is home to "Odense Robot City", where a number of innovative companies within robotics are based, several of which provide automation solutions to hospitals or develop robots for treatments. Hospitals in Southern Denmark also have experience with robots, and Odense University Hospital (OUH) have an innovation centre dedicated to robotics. Southern Denmark is home to several knowledge institutions in the field – both public, such as the University of Southern Denmark (SDU), several centres in hospitals, and the Health Innovation Centre of Southern Denmark (SDSI), as well as private institutions such as the Danish Technological Institute's Centre for Robotics. These and other organisations comprise an ecosystem.

Robots may address multiple challenges in the healthcare sector. There is a shortage of employees in hospitals, and the demographic trend suggests, this challenge will only grow in the future. Robots can potentially free up labour in hospitals, as well as improve the quality of some operations and create a better working environment for employees. Although significant steps have been taken towards more automation and more robots, the potential is still largely untapped.

It is said that it takes a village to raise a child. Similarly, it may take an ecosystem to raise a robot - if by "raise" we mean to shape and develop it so that it can contribute to society. It requires a joint effort from companies, the healthcare system, research institutions, and investors to ensure optimal conditions for healthcare robotics.

To this end, Regional Development of the Region of Southern Denmark[1] has launched an analysis of Southern Denmark's ecosystem for healthcare robotics. The analysis aims to map the ecosystem's stakeholders and its existing strengths and development potential – what works well, and what needs to be strengthened. Furthermore, the analysis provides a range of concrete suggestions for strengthening the ecosystem.

This report is the result of the ecosystem analysis conducted by the Danish Technological Institute from December 2022 to April 2023. The analysis is based on 26 interviews and two workshops with key stakeholders in the ecosystem, on which the Danish Technological Institute have based the identification of eight initiatives to strengthen the conditions for healthcare robotics.

[1] The Danish regions' primary task is the Healthcare services. The regions are also responsible for regional development and running of series of highly specialized social services. The regions are politically governed by democratically elected regional counsils. https://regionsyddanmark.dk/en/about-us/the-region-of-southern-denmark

Although the analysis focuses on Southern Denmark, we hope its findings will be of interest beyond the region. While the ecosystem is anchored in Southern Denmark, it has the potential to create significant value far beyond the region's (and Denmark's) borders.

2.1. Background: Challenges to the healthcare sector and the potential of robotics

Health was the most important issue for Danish voters leading up to the parliamentary election in November 2022. [2] The Danish healthcare sector faces significant challenges, due to a shortage of employees to carry out tasks. The demographic shift towards an older population means that more citizens will require the healthcare system in the future and more people will live with multiple diseases at the same time. Thus, they will have a greater need for treatment and care. At the same time, there are fewer people of working age, and still fewer of them choose educations in healthcare. In short, there are more tasks for fewer employees.

Robotics can contribute to solving this societal challenge in several ways. Some tasks can be automated, whereby a robot takes over the handling of simple tasks, freeing up time for healthcare personnel's other tasks. Other tasks can be augmented, where a robot solution allows staff to perform tasks faster, more efficiently, or more safely than before. This can also release resources in the system. And finally, robots can support in solving tasks where the robot supplements staff in task execution, for example, by supporting heavy lifting or performing repetitive actions.

Thus, robotics can have both direct and indirect positive effects on the healthcare sector. In the short term, labour-saving technology can contribute to time savings, and robotics can provide greater precision in a range of tasks. [3] In the longer term, robots can take over some of the tasks that are most demanding for staff, thereby contributing to a better working environment and less employee sickness.

Technology for the healthcare sector is often assessed based on three parameters: it must improve quality, reduce costs, or increase the availability of treatment – or a combination of all three. [4] Robotics has potential within the first two parameters and can potentially play an important role in strengthening the Danish healthcare sector.

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[2] According to studies by Voxmeter and Megafon. *Kristelig Dagblad* (2022). "Ny måling: Sundhed ligger i top på vælgernes dagsorden", 26 Oktober. https://www.kristeligt-dagblad.dk/danmark/ny-maaling-sundhed-ligger-i-top-paa-vaelgernes-dagsorden; Larsen, J. A & Hansen, L. B. (2022). "Disse emner er de vigtigste for danskerne under valgkampen, vurderer eksperter", *TV2*, 5 Oktober. https://nyheder.tv2.dk/politik/2022-10-05-disse-emner-er-de-vigtigste-for-danskerne-under-valgkampen-vurderer-eksperter

[3] The potential for robots to save time for staff is also a motivation beind the increased use of welfare technology in at the municipal level. *KL & Deloitte* (2022). "Caseanalyse: Tidsbesparende teknologier med dokumenteret effekt", September. https://www.kl.dk/media/51597/caseanalyse.pdf

[4] Uscher-Pines, L. & Martineau, M. (2021). "Telehealth After COVID-19: Clarifying Policy Goals for a Way Forward", January, RAND Corporation. https://www.rand.org/pubs/perspectives/PEA1089-1.html

2.2. Purpose

This analysis will map and support the strengthening of the Southern Danish ecosystem for healthcare robotics. The analysis itself has three main parts.

The first part (Chapter 4) is a stakeholder analysis of the key organisations in the ecosystem. We have identified several types of stakeholders, examples of these stakeholders, and the central resources they contribute to the ecosystem. Furthermore, we have identified the most common types of relationships between the stakeholders. This constitutes the mapping of the ecosystem.

In the second part (Chapter 5), we have identified six strengths and six development potentials for the ecosystem. Strengths are areas where the stakeholders and their relationships excel, and where significant value is created. The development potentials are areas where there is room for improvement or a need for change.

In the third part (Chapter 6), we present eight proposals for specific initiatives that can address some of the ecosystem's development potential and thus support an overall strengthening of the ecosystem. The eight proposals are essentially separate and independent, but the chapter ends with some reflections on an overall vision for the ecosystem that brings some of the proposals together into a comprehensive solution.

2.3. Research design

We utilise a research design centred around qualitative interviews, which were validated through two workshops with stakeholders from the ecosystem. This allowed us to create the best possible space for the stakeholders to share their experiences.

We conducted 26 interviews with stakeholders from the ecosystem. These were selected based on desk research and in collaboration with the Region of Southern Denmark to ensure that all stakeholder types were represented, as shown in Table 1. A list of interviewees can be found in the Appendix.

Table 1. Distribution of interviewees

Stakeholder type	No. of interviewees
User of healthcare robotics (hospitals, municipal institutions, etc.)	4
Investors or investment-related	4
Business clusters	4
Robotics supplier companies and system integrators	10
Universities and other knowledge institutions	4

Interviews typically lasted about an hour. They were semi-structured and conducted by one of two consultants from the Danish Technological Institute's Centre for Business and Policy

Analysis. It should be emphasised that the two interviewing consultants were not a part of the Danish Technological Institute's Centre for Robotics, which is located in Odense and is an integrated part of the ecosystem. Thus, the two can be considered external to the ecosystem.

The 26 interviews were analysed, and the results were presented at two workshops in February 2023. The first workshop took place on February 10th, where input was provided by Regional Development (Region of Southern Denmark); the Health Innovation Centre of Southern Denmark; Odense University Hospital; the University of Southern Denmark, and the Danish Technological Institute. The identified strengths and development potentials in the ecosystem, as well as a draft of the main themes in the proposals, were discussed. Based on feedback from workshop participants, the analysis and proposals were revised.

The revised analysis and list of proposals were presented at a workshop on February 23rd with fifteen participants representing most stakeholder types. In addition, the consultants responsible for the interviews and a business manager from the Danish Technological Institute's Centre for Robotics participated. At the workshop, the findings of the analysis and the proposals were again presented and discussed in groups and in plenary. Feedback from the workshop was subsequently used to develop and refine the analysis results for the final report.

The eight proposed initiatives were sent for initial review and comment by Regional Development in mid-March. The complete report was then sent for review and comment by Regional Development at the end of March. Based on feedback from this, the report was finalised and translated into English in April.

3. Robots in healthcare

This section provides an overview of technological possibilities and challenges for healthcare robotics, which presents a context for the following analysis of the Southern Danish ecosystem for healthcare robotics. The section presents some general distinctions between different types of robotics and provides examples of their use.

As Southern Denmark has historically placed greater emphasis on industrial robots rather than healthcare robots, it is the industrial robots that are produced, sold and used the most in Southern Denmark. When these robots are used in the healthcare sector, they often fall under the category of "robots for staff relief", described below.

3.1. A technological overview

Already today, a range of robot solutions are in use in Southern Denmark – from pilot projects to well-established commercial solutions. The following presents examples of healthcare robotics to provide an idea of the technological scope of the ecosystem. To categorise the robots, DIH-HERO and euRobotics' classifications are used.[5]

3.1.1. Robots for diagnostics

Robots are currently used in various areas of diagnostics. A physical robot component (e.g., robot arm, sensor, or vision technology) collects data that, in combination with artificial intelligence (AI), can provide a diagnostic suggestion that a doctor can evaluate. With increasingly advanced AI technology and better opportunities for using health data, diagnostic robots are becoming more and more precise.

The robot ARTHUR, developed by ROPCA, is an example of this. Here, a robot simulates a doctor's scan of rheumatoid arthritis patients, and using the artificial intelligence product DIANA, provides a diagnostic response. ROPCA thus automates the process of both the forming of ultrasound images and the image assessment in connection with the diagnosis. This saves personnel resources and reduces waiting times for patients. ROPCA's solution is not yet commercialised, but the robot won Kuka's innovation prize in 2022 and is CE approved.[6]

Photo copyright: ROPCA

Endoscopy with pill-camera robots is another form of diagnosis being tested in the ongoing SIGINT project. By using a micro-camera robot in pill form, a patient can perform an endoscopy at home under the guidance of a nurse. Data is transmitted via the robot to a diagnostic system that is read by a doctor. The

[5] https://dih-hero.eu/application-domains
[6] https://ropca.com

technology has the potential to reduce the time spent on endoscopy and thus free up resources. In addition, it is a more comfortable solution for the patient. The project ran from August 2022 to April 2023 and is a collaboration between the German company Corporate-Health, OUH, and hospitals in Spain, Poland, and Germany. The project is funded by DIH-HERO under the EU's Horizon2020 programme.[7]

3.1.2. Robots for surgery – intervention robots

Robots for surgical operations, using vision and sensor technology along with meticulous movements, can perform operations with greater precision than a human hand is capable of. The advantage here is a higher quality of the operation, even though the robot is not labour releasing, as it is still controlled by a surgeon.

The Da Vinci robot is by far the most famous and widely used surgical robot.[8] The robot uses a so-called "master-slave" system, where the doctor controls the robot with their hand movements, allowing the robot arm to perform precise work. The robot is equipped with a camera, enabling the doctor to observe an enlarged image on a screen. The robot was designed by the American company Intuitive Surgical Solutions and is used globally today for many types of operations. In Denmark, the robot is mainly used for gynaecological and urological surgeries.

Photo copyright: Intuitive Surgical, Inc.

3.1.3. Robots for rehabilitation

Robots can support the rehabilitation and recovery of patients, for example by performing repetitive exercises without the need for a physiotherapist. In addition, there are a number of solutions used for neurorehabilitation and gait training. Exoskeletons for rehabilitation are considered a subgroup within this category.

Photo copyright: Life Science Robotics

ROBERT, developed by Life Science Robotics, is an example of this type of robot. ROBERT can assist patients with repetitive rehabilitation exercises by providing resistance on certain motions. This allows patients to train their muscles without depending on help from a physiotherapist to the same degree. In this way, a single physiotherapist can handle rehabilitation exercises with several people at once. Life Sci-

[7] https://corphealth.co/da/startseite-dansk/
[8] International Federation of Robotics (2021): "World Robotics 2021 – Service Robots," p. 166. See also https://www.davincisurgery.com/da-vinci-systems/

ence Robotics is headquartered in Aalborg, and ROBERT has been sold in Denmark, the United States, Germany, and East Asia. ROBERT is used at OUH among other places.[9]

3.1.4. Robots for staff relief

Some robots are classified based on their potential as labour-saving technology, which can release personnel resources. This is the most common type of robot in Southern Denmark. These robots rarely have a direct impact on a patient – they are neither diagnostic, nor do they perform an intervention.

The robot developed at OUH for sorting tissue samples is an example of this type of robot, and it is expected to proliferate to other hospitals in Southern Denmark if and when its resource-saving potential has been validated. The robot archives tissue samples, discards samples, and retrieves samples from the archive when a doctor needs to examine them. The companies Kilde A/S Automation and Siemens have jointly developed the robot, which handles 1,600 samples daily and has reduced the department's resource needs by four full-time employees.[10] LT Automation has developed a similar robot for handling samples.[11]

Photo copyright: Siemens

Other examples include various mobile robots that transport materials such as linen, food, and equipment in most of the hospitals in Southern Denmark, such as OUH, Sydvestjysk Sygehus, and Sygehus Sønderjylland. At OUH, the robot Hubot transports the blood samples that cannot be sent through the tube system,[12] and Sygehus Sønderjylland has also used a variety of different mobile robots.[13]

3.1.5. Robots for patient support

The final category covers robots that provide patient support in a broad sense. For example, both OUH and Sygehus Sønderjylland have had a robot dispensing hand sanitiser in the

[9] https://www.lifescience-robotics.com/
[10] https://new.siemens.com/dk/da/produkter/industri/kundehistorier/utraditionel-robotlsning-sikrer-tid-til-mere-vrdiskabende-opgave.html
[11] https://lt-automation.dk/produkter/
[12] https://fyens.dk/fyn/se-videoen-hej-her-kommer-jeg-hubot-koerer-med-blodproever-paa-ouh
[13] https://www.bfa-i.dk/media/ipsewyhy/praesentation-sygehus-soenderjylland.pdf

lobby.[14] Another example is robots that can dispense medication in dose-packaged portions at specific times, tailored to individual citizens or patients in their own home.[15]

Telepresence robots, which can be used for communication with staff and relatives via screens, speakers and microphones also fall under this last category. However, they are not widely used today because more accessible technologies have emerged.

3.2. Requirements for healthcare robots

Robots require different certifications depending on their intended use. All of these certifications are subject to EU legislation, namely the Medical Device Regulation (MDR) and the Machinery Directive.

The MDR covers robots with medical applications and categorise them according to the degree of impact on the patient. The highest requirements are placed on intervention robots, particularly those that introduce a foreign object into the patient's body. These must undergo a strict approval process. Diagnostic robots are also subject to the MDR and require demanding certifications, as they can have a direct and significant impact on patients' health. However, the requirements for these are generally lower than for intervention robots. Rehabilitation robots also typically fall under the MDR, and their requirements will depend on the degree of influence and risks in interaction with the patient. However, they generally fall into a less demanding category than intervention and diagnostic robots.

The Machinery Directive covers machinery more broadly. Robots that relieve staff by automating parts of a hospital's operations (such as handling packages, linen, or blood samples) do not interact with patients, typically fall under this directive, and they do not require MDR certification. With regard to robots that support patients, approval depends on the degree and nature of the interaction. For example, there is a difference between a telepresence robot which primarily remains stationary and a mobile robot that moves close to patients.

3.3. Market potential and challenges – international experiences

The following section shifts the perspective from the national and regional context in Southern Denmark to an international one in order to briefly provide a non-Danish perspective on both market potentials and challenges for healthcare robotics.

[14] https://fyens.dk/fyn/saa-har-man-set-det-med-talende-robot-koerer-rundt-med-haandsprit-i-forhallen-paa-ouh; https://sygehussonderjylland.dk/om-sygehuset/nyheder/nyhedsarkiv/2020/robot-uddeler-handsprit-pa-sygehuset

[15] E.g., DoseCan, https://teknologi.viborg.dk/vores-projekter/medicinhaandtering/medicinpaamindelse-dosecan/, or Evondos, https://www.evondos.com.

3.3.1. Market potential

At a European level, the trend is clear: Despite the increasing pressure on healthcare systems, and despite the availability of robot technologies and concrete solutions, robotics has not been widely adopted in European healthcare systems, and to date, the effective implementation of new robot-based solutions in healthcare has been a challenge.[16]

Robotics have the potential to solve some of the current challenges in the healthcare sector. The global healthcare robotics market is expected to grow at a compound annual rate of around 21.3% from 2020 to 2027 and is expected to reach a market value of over USD 32.5 billion in 2027.[17]

3.3.2. Research and development

In order to realise this great potential, further systematic support for research, innovation and integration of robotics in healthcare is needed. In addition, a comprehensive interdisciplinary methodological approach to understanding barriers, challenges and perspectives for healthcare robotics is crucial.

An important barrier to the implementation of healthcare robotics across European countries is the lack of evidence for the effectiveness of robotics. This applies to both clinical effectiveness and effectiveness in terms of workforce liberation potential.

Fraunhofer IPA in Germany is noteworthy for their research projects in robots for care and logistics in the healthcare domain, such as CareO'Bot, a mobile service robot intended to serve patients and elderly citizens. [18] Fraunhofer has established testing facilities close to development sites so that they can continuously test in a realistic context. Fraunhofer's projects are largely financed by special research and development funds from the German government.

Spanish company PAL Robotics have also taken steps towards bringing their mobile robot solutions into the healthcare sector in the form of service robots that can serve patients,[19] and F&P Robotics from Switzerland have the same ambition with their LIO platform.[20] None of these products are commercially available.

Of great importance for robot innovation in the healthcare sector over the past five years is the EU-funded DIH-HERO (Digital Innovation Hub Healthcare Robotics), which has built a network and knowledge across European development environments and has supported over

[16] Unpublished research article by DIH-HERO; European deployment of robotics in healthcare – challenges and perspectives, expected to be publlished in spring 2023
[17] https://rb.gy/u4unyo
[18] https://www.care-o-bot.de/en/care-o-bot-4.html
[19] https://pal-robotics.com/robots/tiago/
[20] https://www.fp-robotics.com/en/lio/

50 innovation projects involving healthcare robotics. Several of these projects are still ongoing. In addition, DIH-HERO, as something unprecedented in EU-funded projects, is carrying out eight projects with the aim of implementing healthcare robotics and collecting experience from them. The many projects vary greatly and range from robots that can vaccinate to mobile service robots, rehabilitation robots, and, not least, a range of robots for disinfection in light of COVID-19.[21]

However, only a few of the projects have resulted in commercially mature robot solutions, as the development was aimed at bringing the projects to Technology Readiness Level (TRL) 6-7,[22] where there is still product maturation left. Commercially mature products typically lie at TRL 9-10. The phase from TRL 6-7 is particularly challenging, as funding here typically has to be obtained from companies themselves and their private investors. In addition, the developed products (robots) in this phase must be approved for use (certified), which is a demanding and complicated process with extensive documentation requirements.

In 2022, the European Union co-financed the establishment of four sector-specific AI Testing and Experimentation Facilities (TEFs) with the aim of supporting Europe's position in the development and use of artificial intelligence (AI). One of the chosen sectors is healthcare, and in January 2023, TEF Health, Testing and Experimentation Facility for Health AI and Robotics, was launched.[23] The purpose is to support companies developing AI solutions in the healthcare sector so that their path to the market becomes more efficient, and the credibility of AI solutions is ensured. This is to be done through the establishment of testing facilities, both physical and virtual, where European companies can receive help testing and experimenting with their AI-based technology (both software and hardware) in realistic environments. As part of TEF-Health, tools for standardisation and quality control will be developed, including compliance with legal, ethical, quality, and interoperability standards.

TEF-Health spans a five-year project period and has a budget of EUR 60 million. The partner consortium consists of 31 institutions from ten different European countries, but no Danish partners. The purpose of TEF-Health highlights the link between robots and AI, but it is the AI part that is in the forefront of the overall TEF structure (and thus also the focus of the project). The robots are primarily involved due to their connection to AI.

3.3.3. Encountering the healthcare sector – Japanese experiences

Japan is often seen as a pioneer in robotics. For years, the internet has been filled with images and stories of everything from robotic seals to meet social needs to teddy bear robots that can lift patients, robots for hair washing, and a range of other robots. Japan has had robot

[21] An overview of funded projects is available at: https://dih-hero.eu/awarded-projects/
[22] Technology Readiness Level. The scale is used widely to describe the progress and market maturity og techbologically oriented development projects; in EU-context, e.g., the Horizon-programs. https://innovationsfonden.dk/sites/default/files/2019-03/technology_readiness_levels_-_trl.pdf
[23] https://www.tefhealth.eu/

development as a strategy for addressing the issue of an aging population. However, a new book by James Wright debunks the myth of Japan as a pioneer in robots for the care sector. In the book *Robots won't save Japan*,[24] he describes how robots are not really being used in most places since, in their development, the developers did not take into account all the work that lies outside of using robots, such as preparation, instruction, cleaning, tidying up, and so on. These are tasks that are hidden and ultimately end up taking longer for staff than the care task the robot was supposed to perform. This is, of course, in the care sector, but undoubtedly the results can be applied to other healthcare robotics and to hospitals – and probably also in the Danish context. A study from Aalborg University has examined conditions in Denmark and come to roughly the same conclusions.[25] This underscores the need for a broad range of skills in the development and use of healthcare robotics.

[24] James Wright (2023). *Robots Won't Save Japan*. Ithaca, New York: Cornell University Press
[25] Tornbjerg, K.; Kanstrup, A; Skov, M. & Rehm, M. (2021). "Investigating human-robot cooperation in a hospital environment: Scrutinising visions and actual realisation of mobile robots in service work." *Conference: DIS '21: Designing Interactive Systems Conference* 381-391.

4. Mapping the ecosystem

The following presents a mapping of the Southern Danish ecosystem for healthcare robotics. The chapter begins with an academic discussion of the concept of "ecosystem" to clarify the framework and approach for the subsequent analysis. The next section outlines the key stakeholder categories and specific stakeholders in Southern Denmark who play important roles in the ecosystem. In this review, each stakeholder type is described, and their individual resources are highlighted. Finally, the chapter presents a review of the different types of relationships between stakeholders that characterize the ecosystem. These are the ties that bind stakeholders together and create activity in relation to robots in healthcare.

4.1. Definition of ecosystem

There is no commonly accepted definition of the term "ecosystem" in a business context.[26] In our analysis, we include the following aspects in our definition:

1. the shared interests and mutual dependence among stakeholders within the ecosystem; [27]
2. the different types of stakeholders with both formal and informal relationships;[28]
3. the geographic proximity of actors in the ecosystem. One of the prerequisites for an ecosystem is the development of a critical mass of stakeholders and activity. [29]
4. the sociocultural structures in the ecosystem. Every ecosystem does things "in its own way", and constructive participation in the ecosystem requires stakeholders to understand and follow social codes.[30]
5. Ecosystems evolve over time. Ecosystems are not static but constantly changing due to the actions of stakeholders, political conditions, macroeconomic trends, etc.[31]

These aspects are assumptions that underpin the following definition of a business ecosystem, which will be used in our analysis: *A business ecosystem is a geographically bounded network of organisations and companies consisting of both public and private stakeholders of different*

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[26] Brown, R. & Mason, C. (2017). "Looking inside the spiky bits: a critical review and conceptualisation of entrepreneurial ecosystems." *Small Business Economics*, 49, 11-30.

[27] Stam, E. (2015). "Entrepreneurial ecosystems and regional policy: a sympathetic critique." *European Planning Studies*, 23(9), 1759–1769, p. 1765.

[28] Mason, C. & Brown, R. (2014). *Entrepreneurial ecosystems and growth-oriented entrepreneurship*. Paris: Final Report to OECD http://lib.davender.com/wp-content/uploads/2015/03/Entrepreneurial-ecosystems-OECD.pdf, p. 5.

[29] Feldman, M. & Braunerhjelm, P. (2006). "The genesis of industrial clusters." *Cluster genesis: Technology-based industrial development*, 1, 1–13; Audretsch, D. B. & Belitski, M. (2017). "Entrepreneurial ecosystems in cities: establishing the framework conditions." *The Journal of Technology Transfer*, 42, 1030-1051.

[30] Venkataraman, S. (2004). "Regional transformation through technological entrepreneurship." *Journal of Business Venturing*, 19(1), 153–167; Spilling, O. R. (1996). "The entrepreneurial system: on entrepreneurship in the context of a mega-event." *Journal of Business Research*, 36(1), 91–103, p. 92.

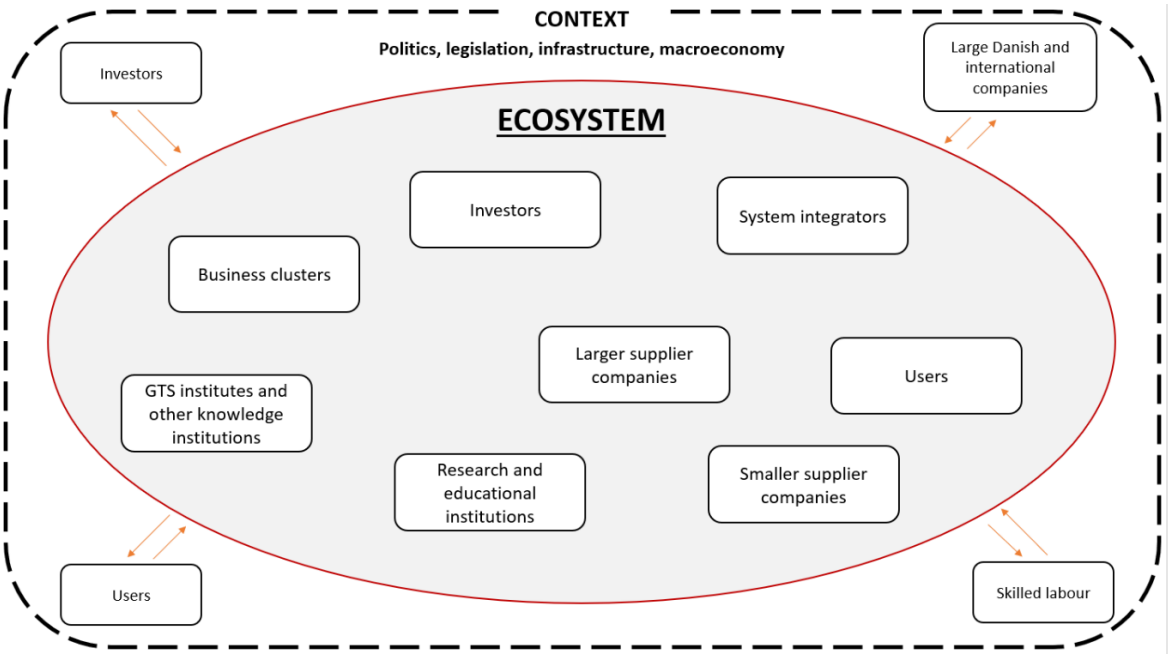
[31] Borissenko, Y. & Boschma, R. (2016). *A critical review of entrepreneurial ecosystems: towards a future research agenda, No 1630*. Section of Economic Geography: Utrecht University.

types within the same sector, where stakeholders interact regularly and mutually support each other's success.

The ecosystem is defined as the *network* of participating stakeholders, not the participating stakeholders themselves. This approach can be referred to as relational,[32] as we focus on the ties between the network's participants more than the participants themselves. We are therefore interested in how each participant is connected to, uses, and perceives the ecosystem and each other.

We use the model for ecosystems in Figure 1 as a starting point. The figure illustrates the stakeholders that populate ecosystems and how the ecosystem is influenced by external factors. The model is an *ideal type* and presents a simplification of reality for analytical purposes. The real network of stakeholder types is even more complex, but the figure can provide an overview that is useful in mapping the ecosystem.[33] It should therefore be emphasised that the figure is not exhaustive. For example, business incubators (general and specialised business support) could also be included. However, these have played a smaller role in the analysis and are therefore omitted.

Figure 1. Ecosystem model



[32] For an indepth description of relationalism in network theory, see Erikson, E. (2013). "Formalist and relationalist theory in social network analysis," *Sociological Theory* 31(3). p. 226

[33] For an account of ideal-typical methodology, see Jackson P. T. (2016). *The Conduct of Inquiry in International Relations: Philosophy of Science and its Implications for the Study of World Politics*, 2. ed. London: Routledge. Chap. 5.

The boxes within the ecosystem in Figure 1 represent the stakeholder types that make up the ecosystem. The four boxes outside the ecosystem represent other important stakeholder types that impact the ecosystem without being a part of it.

There are also individuals and organisations that overlap or connect different stakeholder types. For example, the newly established Odense Robotics StartUp Fund[34] lends money to robot startups (similar to some forms of investors), but the fund is also in a partnership with Odense Robotics, a business cluster, and the Danish Technological Institute, a knowledge institution. The stakeholder types are therefore not as separate as the model suggests.

Relationships between stakeholders can take various forms and be both formal and informal. The following examples are some of the most typical types of relationships:

- commercial relationships (typically between businesses that sell and either the government or another business that buys)
- sharing of knowledge (e.g., between knowledge institutions and others)
- investments (between investors and businesses)
- collaboration on innovation and testing (between businesses and knowledge institutions or customers)
- education collaboration and internships (between educational institutions and businesses).

Different stakeholder types have different resources that affect their function and relationships in the ecosystem. One stakeholder has capital, another has knowledge, and a third has testing facilities, etc. These resources define which relationships a stakeholder can meaningfully engage in and therefore the overall activity in the ecosystem.

The ecosystem is situated within a broader political, regulatory, infrastructural, and macroeconomic context that dictates the political rules of the game, the regulatory regime (within Denmark and the EU), the infrastructural framework, and the socio-economic conditions for the ecosystem. For example, the shortage of labour in hospitals and the demographic development in Denmark are important macroeconomic factors that affect the demand for robotics today and create more favourable conditions for the ecosystem.

4.2. Stakeholder analysis

In Table 1 of chapter 2, a categorisation of the 26 interviews into five overarching categories was presented: robotics users; investors or investment-related; business clusters; suppliers and system integrators; and universities and other knowledge institutions. In the following

[34] https://www.teknologisk.dk/ydelser/pengestaerke-direktoerer-og-danske-fonde-donerer-til-ny-fond-for-robotivaerksaettere/44523

stakeholder analysis, the latter two categories are further subcategorised. Suppliers are divided into "small supplier companies"; "large supplier companies", and a distinction is made between "Universities and other educational institutions" and "knowledge institutions". The latter includes both public knowledge institutions and government-approved research and technology organisations (GTS) institutes.

Some of the described stakeholders overlap several categories in their functions and institutional affiliations. However, even though the categorisation is not perfect, it can help to create an overview of stakeholder types and their characteristics.

The following pages go through these stakeholder types (one by one), their respective functions in the ecosystem and their resources.

4.2.1. Users – hospitals, municipal institutions, etc.

The hospitals in Southern Denmark are the primary users of healthcare robotics in the present analysis. Though, automation technology can also be found in municipal contexts and in pharmacies. Hospitals play an important role in testing and evaluating new robots, typically through their participation in development projects.

Odense University Hospital (OUH) is the largest hospital in Southern Denmark and have placed strategic emphasis on robotics, e.g., by establishing the Centre for Clinical Robotics (CCR), which helps companies understand the healthcare sector's needs and to develop and test their robotics solutions. The Centre for Clinical Robotics is a collaboration between OUH and the Mærsk McKinney-Møller Institute (MMMI) at the University of Southern Denmark (SDU), which researches robotics. Thus, the Centre for Clinical Robotics links robotics research with the clinical needs identified in the hospital.

Since hospitals are the end-users of robotics, they have the greatest knowledge of user needs. This may include general conditions in the healthcare sector or specific product requirements that apply to a hospital. Several hospitals, including Sygehus Sønderjylland, also have years of experience from robot development projects and implementation of robots in operations. Therefore, they know many of the typical challenges for robots in healthcare. Finally, hospitals can provide test facilities for the testing of new technology.

4.2.2. Larger supplier companies

The larger supplier companies include companies that produce and have had commercial success with their robot solutions in and outside Denmark. Unlike system integrators, supplier companies develop and sell robots, but they typically play a smaller role in the concrete integration of the technology at the buyer's premises. Suppliers sell specific robots that may be integrated into larger systems of others. Their direct customers are therefore often other

companies and not the hospitals themselves. Universal Robots and MIR are the largest manufacturers of their own robots in Denmark. Abena and Linak are larger Danish supplier companies, although their robots make up a relatively small part of their products.

The larger supplier companies' main resources are their deep technical knowledge of robotics and its possibilities, as well as their knowledge of market dynamics and their market access in Denmark and internationally. In addition, they have capital that can be used to support innovation and commercialisation of new technologies, either through their own projects or through investment in or acquisition of smaller companies.

4.2.3. Smaller supplier companies

Like the larger supplier companies, the smaller supplier companies develop specific robot solutions. The difference is that the smaller supplier companies are younger and have had less commercial success. They may be small companies with limited revenue (such as PTR Robots) or startup companies that are developing, testing, and seeking approval for their product (such as Lifeline Robotics and ROPCA). The smaller companies may either try to market their products directly to the healthcare sector, or to other companies. In the case of medical robots, such as Lifeline Robotics' sampling robot and ROPCA's scanning robot, the smaller supplier company also gains more in-depth knowledge of the high requirements for robotics for the healthcare sector.

The smaller supplier companies have more specialised technological knowledge of their own product and thus often also of specific healthcare aspects related to their technology, but they do not have the same market experience as the larger companies.

4.2.4. System integrators

Unlike supplier companies, system integrators are primarily characterised by function in integrating automation and robotics into users' existing operations rather than developing new robot technology. System integrators generally have a closer dialogue with hospitals, since the development and integration of a robotic solution for handling items, such as supplies or blood samples, is a comprehensive process that typically requires ongoing support and development.

System integrators are not limited to the healthcare sector. For example, Gibotech and LT-Automation have been developing automation solutions for the industry for many years before entering the healthcare sector. The system integrator Holo has only recently had an encounter with the healthcare sector through a development project for drone transport of blood samples between Ærø and Svendborg Hospital.

System integrators often get closer to the users of robotics than supplier companies do, and they have a more in-depth knowledge of hospitals' needs. Integrator companies usually do

not need special medical approval for their products. Therefore, they can more easily translate knowledge and experience from the industry to the healthcare sector (and vice versa).

4.2.5. Business clusters

The ecosystem for healthcare robotics in Southern Denmark is primarily associated with two business clusters within the national, publicly funded Danish innovation and business support system: Odense Robotics and the Danish Life Science Cluster. The business clusters facilitate knowledge sharing between users and companies within their respective areas, and they also participate in innovation processes for new products. The business clusters also provide a framework for several networking groups and have funding resources for smaller projects, where collaboration is established between companies and academic institutions.

Odense Robotics have the stronger presence of the two business clusters in Southern Denmark. However, Odense Robotics predominantly have an industrial focus, and healthcare play a relatively small role in the business cluster's activities. The Danish Life Science Cluster is headquartered in Copenhagen but is also present in Odense and has healthcare as its focus. The two business clusters, together with the Health Innovation Centre of Southern Denmark host the Network for Mobile Robots in Healthcare, which gathers stakeholders in the field four times a year.[35]

The business clusters' greatest resources are their extensive networks with a range of different stakeholders in the ecosystem, which they regularly gather and facilitate knowledge sharing among. Additionally, the business clusters have knowledge about innovation processes and access to public funding.

4.2.6. Research and educational institutions

Syddansk Universitet (SDU) is the primary university in Southern Denmark (with a presence in Odense, Esbjerg, Kolding, and Sønderborg). The Mærsk McKinney Møller Institute in Odense research robotics, AI, and drones and is Southern Denmark's primary educational institution for robot developers. Startup companies also reside at SDU's campus, where they gain access to the university's students through study jobs, internships, and larger school projects.

UCL Erhvervsakademi and Professionshøjskole also play an important role in education in the ecosystem for the user side. UCL offers education for professions such as nursing, occupational therapy, and physiotherapy, all of which will potentially work with robotics. As part of its healthcare education programmes, UCL offers a course on technology understanding.

[35] https://www.danishlifesciencecluster.dk/netvaerksgrupper/netvaerk-for-mobile-robotter-i-sundhedssektoren/

SDU and UCL are the primary channels for specialised labour in the healthcare and robotics areas in Southern Denmark. In addition, SDU also provides research-based knowledge and laboratory facilities that companies can buy access to in collaborative projects. Finally, SDU delivers students as labour to startups that are part of the campus environment.

4.2.7. GTS institutes and other knowledge institutions

The Danish Technological Institute is a government-approved research and technology organisation (GTS) in Denmark, and the institute's Centre for Robotics Technology is located in Odense. The GTS institute Force Technology also have several addresses in Southern Denmark, including Odense, Esbjerg, and Middelfart. The GTS institutes participate in development projects with companies and public organisations, and they conduct analyses of technology-related issues, financed in part by the Ministry of Education and Research. They also sell consultancy services and access to testing and demonstration facilities. The Danish Technological Institute is part of the European network on healthcare robotics, DIH-HERO.

The other most important knowledge institution is Health Innovation Centre of Southern Denmark (Syddansk Sundhedsinnovation, SDSI), which is the central innovation unit of the Region of Southern Denmark. Health Innovation Centre of Southern Denmark facilitates collaboration between companies and the healthcare sector in Southern Denmark, as well as organises networking activities, and provides knowledge on a consultancy basis. Southern Denmark's hospitals have an annual time allocation with Health Innovation Centre of Southern Denmark, which they can use to facilitate projects on the development and testing of technological and digital solutions.

The GTS institutes and the Health Innovation Centre of Southern Denmark's most important resources are their broad knowledge of both technology and demand, which companies and users indirectly or directly use by involving them in specific development projects. The Danish Technological Institute and Health Innovation Centre of Southern Denmark are both located in Forskerparken in Odense and regularly host joint events such as the Week of Health Innovation (WHINN) and the Hospital Automation Summit.

4.2.8. Investors and investment-related stakeholders

There are several networks for investors in Southern Denmark, such as Business Angels Southern Denmark and REInvest Robotics. Other Danish investment/venture capital firms, such as Nordic Eye, are also active in the ecosystem. REInvest Robotics was founded by Esben Østergaard who was a co-founder of Universal Robots.

Several organisations also support the connection between companies and investors. Invest in Odense works to attract capital, companies, and labour to the city's businesses in the same way that the Ministry of Foreign Affairs' Invest in Denmark does at the national level. Both

regularly organise international delegations to the ecosystem, often in collaboration with Healthcare Denmark[36] or The Health Innovation Centre of Southern Denmark.

Science Ventures Denmark is owned by SDU and helps spin-off companies from the university establish themselves and find capital. Science Ventures Denmark have played a role in the establishment of both Universal Robots and Lifeline Robotics. There are of course also many informal relationships between individual investors.

Investors' most obvious resource is capital, which is particularly necessary for startup companies. However, investors also typically contribute with a relevant business network – often outside of Southern Denmark – and with knowhow related to business management, which can again be especially valuable for young companies in the process of establishing themselves.

4.3. Relationships between stakeholders

As described in the definition of an ecosystem, this analysis emphasises the relational aspect of the ecosystem. Thus, it is not only relevant to list the stakeholders in the ecosystem, but also to investigate the different types of relationships. It is in these relationships that the ecosystem thrives.

The following section discusses some of the different types of relationships and the participating stakeholders.

4.3.1. Commercial relationships

The most fundamental relationships in a business ecosystem involve the buying and selling of goods. In the Southern Danish ecosystem for healthcare robotics, the buyer is often a public hospital, but can also be private or municipal stakeholders. The seller is either a robot supplier or a system integrator.

When a purchase is large enough, the procurement process takes the form of a public tender. This will be the case for large automation solutions for hospitals or for the purchase of many smaller robots. Alternatively, hospitals can deal directly with supplier companies if it concerns smaller purchases.

Commercial relationships also describe buying and selling between companies, such as when a company acts as a subcontractor to another.

[36] https://www.healthcaredenmark.dk/about-us/

4.3.2. Relationships centred on research and development.

Prior to commercial relations (procurement), there are often collaborations on the development of new robotic technological solutions. Such development projects are typically funded by (one or more) grants, and they typically facilitate a product moving from technology readiness level (TRL) 2-4 to 5-7; that is, from a low to a higher level of technological maturity without being so fully developed that the new technology can be commercialised. Suppliers and buyers typically carry out such projects together with a university such as SDU or knowledge institutions such as the Danish Technological Institute.

Before a sale, there is often a dialogue about the technological solution and its value (market dialogue) and a process of developing and/or adapting the product, when it comes to healthcare robotics. Automation systems for hospitals often need to be customised to a significant extent for each individual hospital[37] and sometimes developed specifically to meet the needs of a hospital. Therefore, system integrators and the hospital are often in close collaboration for a longer period.

The same applies to clinical robots, where the robot supplier needs access to clinical data and knowledge from the hospitals before the technology can obtain the necessary approvals and be marketed.

4.3.3. Relationships focused on knowledge sharing and network

Within the ecosystem for healthcare robotics, several events are held to build connections between the stakeholders and to facilitate knowledge sharing between them, especially between the companies and the hospitals. These events are typically a collaboration between Odense Robotics, the Danish Life Science Cluster, the Health Innovation Centre of Southern Denmark, the Danish Technological Institute, and others.

Relationships can also focus on knowledge sharing when companies or other stakeholders in the ecosystem participate in research with a public purpose – for example, by participating in interviews for the present analysis. Here, stakeholders set aside time to convey their strategic perspective on (and experience of) common issues, and these experiences are analysed and communicated by the analysing stakeholder, which is typically a business cluster, university, or knowledge institution.

Activities like these can lead to larger joint development projects typically funded externally by the EU's Horizon Europe, Innovation Fund Denmark, or the EU's Interreg programme.

[37] Andersen, N. K. (2022). *Robotter i sundhedssektoren: Innovation og barrierer i Danmark og Verden,* Aarhus: Danish Technological Institute

4.3.4. Collaborative marketing relationships

Marketing the ecosystem does more than just draw attention to the ecosystem of the companies and positive technology cases. Various stakeholders in the ecosystem regularly enter collaborative relationships to market the companies' products or the technological solutions that are already in operation in hospitals. Here, companies and hospitals collaborate – often in partnership with the Health Innovation Centre of Southern Denmark, Invest in Odense, or the Danish Foreign Ministry's Invest in Denmark – to host visiting delegations from the rest of the country or from abroad.

5. The Interreg programme as a framework for Danish-German cooperation

Through the EU Interreg programme for Danish-German cooperation, stakeholders in Southern Denmark and Northern Germany have carried out development projects in the healthcare sector for several years. Cross-border professional relationships have thus been developed, which can also provide access to the German market for Danish stakeholders.

During the programme period (2014-2020), 11 projects focusing on the healthcare sector were implemented under the Interreg programme "Priority 1 Innovation".[38] These encompass much more than just robotics, but there are projects with direct relevance to robotics:

- ACCESS & ACCELERATION: New ideas, technologies, and products in the healthcare sector to address challenges and demographic changes, changed treatment conditions, and rising costs
- Health-CAT: Needs assessment, development, and testing of a robot prototype for hospitals and nursing homes
- HanDiRob: Design of a mobile, modular robot system to motivate people to disinfect their hands.

Although the projects have addressed a wide range of issues within the healthcare sector – and thus do not have a particular focus on robotics – the projects have nevertheless opened a door to develop new collaborative relationships for the benefit of the Southern Danish ecosystem for healthcare robotics. In the current programme period (2021-2027), there are still opportunities, as DKK 698 million has been allocated to Danish-German cooperation projects, of which approximately 35% is allocated to the priority "An Innovative Region".

The Northern German research and healthcare environment is broad. Life Science Nord (LSN) – Life Science Cluster Hamburg and Schleswig-Holstein – is a cluster organisation for medical technology, biotechnology, and pharma, which includes the entire value chain from research, production to consumers/users.[39]

Some members of LSN are interested in robotics, but only a few stakeholders, such as BAHEAD[40] and Eppendorf,[41] focus on robots in logistics, automation, and artificial intelligence. In addition, the Fraunhofer Research Institution for Individualized and Cell-Based Medical Engineering IMTE is working on transferring robot technology to the healthcare sector.[42] In 2023, Fraunhofer is in the process of establishing the Lübeck Innovation Hub Surgery, a "surgery

[38] https://www.interreg5a.eu/dk/wp-content/uploads/sites/4/2023/03/Interreg-Resultater-Projekter-2014-2020-DK.pdf
[39] https://lifesciencenord.de/en/about/the-association.html
[40] https://lifesciencenord.de/en/membership/member-directory/detail/bahead-gmbh.html
[41] https://corporate.eppendorf.com/en/16092022-eppendorf-expands-high-tech-site-in-juelich-and-celebrates-topping-out-ceremony-for-multifunctional-building/
[42] https://www.imte.fraunhofer.de/en/Kompetenzfelder/Medizintechnik/Medizinische-Robotik-und-Training.html, see also the article "Rise of the robots" in https://lifesciencenord.de/files/Magazin/LSN_Magazine_2023.pdf

operating theatre," which is a testing and development facility for the use of robots and artificial intelligence in surgeries. The facility is intended to function as a replica of an operating room with the aim of developing, improving and spreading the use of robots and also to serve as a training facility for hospitals to support them.

Finally, "Gesundheitswirtschaft Hamburg" should be mentioned as a sister organisation to LSN, which deals with digitization and health economics,[43] as well as the ambition to develop Northern Germany into "an ecosystem for medical AI".[44]

We assess that Danish-German cooperation holds significant potential, not only within robotics for logistics and automation, but also within a broader range of health technology and digital solutions e.g., operating rooms, laboratories, drones, and rehabilitation (lifting and training, including monitoring). Collaboration could also involve introducing Danish companies to the German market through showcases. The collaboration opportunities seem significant, which is why it may be considered to anchor this in a general cooperation agreement, where the overall terms for the cooperation are specified and agreed upon, making it easier to enter a cooperation agreement for specific projects.

[43] https://www.gwhh.de/startseite/
[44] "Creating value in ecosystems" in https://lifesciencenord.de/files/Magazin/LSN_Magazine_2023.pdf

6. Analysis of the ecosystem's strengths and development potential

The purpose of this analysis is to uncover the existing strengths and potential for development in the Southern Danish ecosystem for healthcare robotics. The initial approach was a SWOT analysis, which asked the interviewees for their views on strengths, weaknesses, opportunities, and threats in the ecosystem. However, through the interviews, it became clear that the main findings were related to strengths and weaknesses, while interviewees had difficulty formulating concrete threats. Weaknesses mainly took the form of proposals to improve the ecosystem. For this reason, the SWOT analysis was reduced to a presentation of the perceived strengths and potentials for development of the ecosystem. The discussion of the future perspective follows in the specific proposals for strengthening the ecosystem presented by the analysis.

Therefore, the following section reviews key themes and commonalities in the strengths and development potentials of the ecosystem that the interviewees identified, which were subsequently validated in two workshops.

6.1. Strengths of the ecosystem

The following describes six strengths of the Southern Danish ecosystem for healthcare robotics. These strengths were identified by the interviewees and represent areas where the ecosystem's stakeholders benefit from each other.

6.1.1. The industrial robot business environment

The ecosystem for healthcare robotics is built on an existing environment for robotics in general. In Southern Denmark, and especially in and around Odense, there is already significant and internationally oriented commercial activity in robot companies that have experience in product development, sales, and all other aspects of business operations. These experiences and resources spill over into the healthcare sector.

There is already synergy in the collaboration between robot companies and their investors, supported by Odense Robotics' networking activities. The stakeholders know each other and can rely on each other.

The concentration of companies working with robotics combined with SDU's research in the field also makes Southern Denmark an attractive destination for specialised international labour in robotics. Foreign robotics specialists can move without being tied to any single job, as there are several relevant job opportunities. This critical mass of robot companies is important for international recruitment.

6.1.2. Education – access to skilled labour

Relevant education related to healthcare robotics is offered at both SDU and UCL. SDU offers robotics education that directly supports local robot companies. UCL have placed increasing

strategic emphasis on building technology understanding among students in healthcare education, such as nurses, occupational therapists, and physiotherapists, so they understand the potential of new robot solutions, contribute to development and adaptation, and implementation. In this way, education supports both those who develop and those who use health technologies.

SDU and companies also benefit from each other during the education process. Several startup companies are located at SDU and thus have access to students as labour, and students can participate in education-related programmes with companies, such as in connection with major tasks.

Finally, several stakeholders, including the business cluster Odense Robotics, play an important role in supporting the attraction of relevant labour and relevant education to Southern Denmark.

6.1.3. Strong and open networks

There is a strong network among the stakeholders in the Southern Danish ecosystem for healthcare robotics. The different stakeholders have regular contact at various events, through the Network for Mobile Robots, or in the existing working group with participants from Health Innovation Centre of Southern Denmark, Danish Technological Institute, Danish Life Science Cluster, Odense Robotics, and Centre for Clinical Robotics. These network activities are often open and free for participants, and therefore create good conditions for stakeholders to build personal relationships in the ecosystem.

By bringing together people from different types of organisations, the networks also create opportunities for stakeholders to hear perspectives from other stakeholder types. Companies can learn about public sector conditions, users can get an impression of the challenges faced by companies, and knowledge institutions can convey their insights.

These networks are supported by the geographical proximity of many of the stakeholders. The Danish Technological Institute, Health Innovation Centre of Southern Denmark, and Danish Life Science Cluster are neighbours in Forskerparken, and SDU and the new OUH are located close by. This proximity makes it easier to organise events together, and it supports informal contact (as it is easy to meet).

6.1.4. Strong research and development environment

Several public institutions in Southern Denmark support the development of, and research into, healthcare robotics. The Centre for Clinical Robotics play an important role as a resource for both OUH and for companies that have a natural point of contact with the hospital. Health Innovation Centre of Southern Denmark supports the regional hospitals' collaboration with companies through knowledge, networks, and development processes. OUH's innovation funds also support startup companies.

Some of the hospitals in Southern Denmark, such as Sygehus Sønderjylland, have gained extensive experience in testing robots for various tasks over the years. This experience is a great resource in the assessment, development, and testing of new robotics technologies – or even just ideas for new technologies, as several hospitals are aware of the most common challenges that companies need to be aware of. They can therefore quickly provide qualified input for the technology.

SDU's research, especially at the Mærsk McKinney Møller Institute, is a great resource for the ecosystem. Several companies have drawn on the university's researchers in the development of their own products. Research at SDU has also resulted in the establishment of new companies on several occasions. In this regard, Science Venture Denmark play a supportive role by helping in the process of business formation and investment acquisition. There are thus dedicated resources to help researchers transform their knowledge and ideas into an actual business.

On the more informal side, the ecosystem is supported by the ongoing dialogue that takes place between hospitals, where successful solutions are showcased. If a hospital experiences success with new technology, they are happy to showcase the technology to others, and thus the positive story spreads quickly. This creates knowledge sharing among hospitals, but it is equally valuable for companies as the cases spread naturally to other potential customers.

Finally, companies in the ecosystem are getting better and better at orienting themselves towards the unique user needs found in the healthcare sector. Selling technology to the healthcare sector involves different product requirements, and the sales process is different than that of selling to industry. Therefore, it is a strength in the ecosystem that several companies have gained experience in selling to the healthcare sector.

6.1.5. The brand “Odense Robot City” and its international orientation

Odense has been working on its image as the "Robot City" for many years. The brand is supported by the municipality, politicians, and by the fact that Denmark's robot cluster is called "Odense Robotics." And the brand works. It is recognised internationally and helps attract labour and investments, as well as an awareness of Odense.

Within health innovation specifically, Southern Denmark is also recognised as a leader in Europe. Already in 2016, under the leadership of The Health Innovation Centre of Southern Denmark, Southern Denmark received the highest rating from The European Innovation Partnership on Active and Healthy Ageing, which works to promote innovation.[45]

[45] https://syddansksundhedsinnovation.dk/en/projects/the-region-of-southern-denmark-and-the-european-innovation-partnership-on-active-and-healthy-ageing

The ecosystem's emerging reputation in both health and robots makes it an attractive partner for foreign stakeholders and EU projects. The Danish Technological Institute already represents the ecosystem in the European DIH-HERO and euRobotics forums, and this helps to create awareness of the opportunities in Southern Denmark.

In fact, several stakeholders attract international attention to the ecosystem, including SDU, the Ministry of Foreign Affairs, Invest in Odense, Healthcare Denmark, and many others. Export promotion and delegation management support companies' opportunities to sell abroad and create potential interest among large international companies.

Several Danish companies in the ecosystem are also active in international markets and have contacts and knowledge of needs in other countries. These successful companies can help smaller companies by taking them along during sales promotions. In this way, the companies help each other and share networks.

6.1.6. Enthusiastic individual investors

The number of Danish investors with experience in robotics for the healthcare sector is still low. However, some of these investors show great commitment to the ecosystem. They invest in startups with long time horizons, and they share their experiences from successful robot companies within the network. The most prominent investors in the environment today have experience from large successful companies such as Universal Robotics and MIR, and it is this experience that they spread when they invest in new robot companies.

These enthusiasts are also important for the ecosystem, because they have a personal network and are recognized by other investors. Their investment in a company can therefore be considered a stamp of approval by other investors. They can help new companies with the difficult task of finding new investors who are willing to invest in robots for the healthcare sector by vouching for them.

6.2. Development potential for the ecosystem

In the following, six development potentials for the Southern Danish ecosystem for robotics for the healthcare sector are discussed. The development potentials are identified by the interviewees and represent areas where the ecosystem's stakeholders see weaknesses, obstacles, or unrealised potential.

6.2.1. Challenges with scaling robotics solutions

The first challenge is more related to the healthcare sector, but it has significant implications for companies in the ecosystem. There is a fundamental challenge with scaling robotic solutions to the healthcare sector, stemming from the fact that all hospitals are different and

therefore have different requirements for products.[46] In other words, it is difficult to establish larger-scale production and thus achieve economies of scale, as each customer requires extensive customization of the product.

The different requirements in hospitals make product development and customisation complex. Supplier companies must therefore be willing and able to support development for a long time, even if the solution may not be sold elsewhere. If support for the technology is discontinued, hospitals will eventually stop using the robots.

This leads to a chicken-and-egg situation where robot products are not developed because companies do not earn enough money from them. And the healthcare sector avoids buying robot technologies because they perceive them as underdeveloped.

The challenge affects startups, particularly, because they rely on success for their first products. When a company is successful with new robot technology, it is often system integrators or side-stepping companies that can finance development and sales through other operations.

6.2.2. Strengthening the dialogue between clinical needs and technological solutions

Although there are several opportunities for robotics companies and buyers to meet and interact in the ecosystem, there is still significant potential to strengthen the link between clinical environments and technical environments (companies, research, and healthcare institutions). Sometimes, technological answers to clinical needs – or clinical applications for new technologies – already exist, and there is an opportunity to create value for both the healthcare system and companies.

The challenge is also expressed in other ways. Often, companies involve the buyer in the development phase, for example by contacting OUH's Centre for Clinical Robotics or other relevant stakeholders, only in the later stages. This can lead to resource waste when adjustments, that could have been foreseen, need to be made.

Moreover, at hospitals, there is no systematic anchoring of innovation at the clinical level. This means that clinicians who have ideas for new technologies and know the clinical needs do not have very good opportunities to pursue them. Some good ideas are therefore forgotten instead of being turned into concrete solutions that could enrich the entire healthcare system.

[46] Andersen, N. K. (2022). *Robotter i sundhedssektoren: Innovation og barrierer i Danmark og Verden,* Aarhus: Danish Technological Institute.

6.2.3. Insufficient emphasis on commercial considerations when selecting development projects for grants.

Historically, there have been several development projects focused on healthcare robotics. However, many of these have not resulted in anything that could be commercialised. Part of the problem has been that projects were initiated to solve very unique problems, not necessarily the challenges shared by the majority. Additionally, solutions are often not fully market-ready when the project terminates. Even if a project delivered a solution that responded well to the specific challenges, the scaling potential is often too small for any company to continue with the technology.

Therefore, there is a potential for development by placing greater emphasis on generic problems and bringing solutions further in market maturity when selecting projects for funding. This could potentially increase the proportion of development projects that end up as commercialised robots, creating value for the buyer and the company.

6.2.4. Fleet management and integration of different robot systems is difficult, due to different IT systems.

Hospitals with different robot systems in operation face a major challenge in fleet management and integration. Since the robots come with their own IT systems and are programmed in different languages, it is difficult to integrate the hospital's fleet management into a single platform.

These differences between the robots also lead to hardware challenges. If a specific mobile robot requires a special sensor to be installed on the hospital's doors or elevators for the robot to open them, then five different robots may require the installation of five different sensors. This process is costly and cumbersome for hospitals and makes it difficult to implement future robot systems.

6.2.5. The inflow of resources to the ecosystem should be strengthened through more external input.

One of the strengths of the ecosystem is also a challenge. Due to the many resources in the ecosystem for healthcare robotics in Southern Denmark, there is a tendency for stakeholders to seek knowledge, collaboration, capital, and expertise within the ecosystem rather than seeking potential partners in other parts of Denmark or internationally. To put it bluntly, there may be a tendency for the ecosystem to close in on itself. This must be avoided.

Therefore, it is a development potential to continue to seek external collaboration to ensure that the ecosystem receives a supply of resources from outside. This can involve capital in the form of investors and companies. It can involve competent labour, including entrepreneurs and potential board members who can contribute expertise within the business community. And it can involve knowledge from educational institutions outside Southern Denmark, who should be invited to share their knowledge in networks and events in the ecosystem.

6.2.6. Lack of clarity regarding testing and documentation requirements for healthcare robotics

As mentioned earlier, the healthcare sector is subject to strict legislation, and hospitals require documentation that robot technologies are both safe and provide the benefits promised. However, among companies, there is often a great deal of confusion about exactly what type of documentation is required and, especially, how it is obtained.

The problem is twofold. On one hand, it concerns the clinical tests that must be performed with robots for the treatment of patients. Here, the supplier must demonstrate scientifically that the robot delivers valid results and is reliable. This is not only about the CE certification under MDR, which can be a challenge. Even after CE approval has been obtained, hospitals may require evidence of the precision and usefulness of a robot's work.

The second problem concerns the business case. If the robot is sold as labour-saving, the company should be able to document the specific number of hours that can be saved with the technology. To provide this calculation, the company depends on a range of information about the hospitals. How often is the task that the robot is taking over performed? How long does it take? How many employees are involved? What types of employees are involved? Only then can the company provide an estimate of the actual savings. Ideally, the robot should have been involved in a pilot trial, from which the calculations can be made.

This is particularly problematic for companies trying to sell their first product and therefore do not have existing cases and customers to cite for validation of its potential. Once a robotic solution is in operation in one place, the company can always refer to it.

7. Initiatives to strengthen the ecosystem

The following presents a range of proposals for initiatives that could strengthen the Southern Danish ecosystem for healthcare robotics. The initiatives address different aspects of the development areas that were identified earlier and provide examples of which types of stakeholders could be involved in realizing the initiatives.

The initiatives are presented separately and are, in principle, independent of each other. However, we will also consider how the initiatives could be combined and support each other.

The following initiatives were either directly proposed by stakeholders in the ecosystem (and subsequently qualified in the analysis process) or were analytically derived by the Danish Technological Institute based on the identified strengths and development areas. Therefore, there is no single stakeholder who can be attributed to one or more proposals. They are all an expression of an overall assessment and analysis.

The identified initiatives to strengthen the ecosystem – in an unordered sequence – are:

1. Allocate funds specifically for the development of robotics closer to final use in the healthcare sector.
2. Establish an international testing environment for healthcare robotics
3. Strengthen counselling for businesses regarding public procurement processes and business cases.
4. Define IT standards for healthcare robotics.
5. Create a technology forum for knowledge sharing, market dialogue, and problem-solving.
6. Strengthen business counselling regarding CE certification for medical devices.
7. Strengthen the focus on commercial scaling in development projects.
8. Strengthen the marketing of Odense as a Robot City with a healthcare perspective.

7.1. Research, development and innovation funding

Proposal	Allocate funds specifically for the development of robotics closer to final use in the healthcare sector
Purpose	To strengthen the resource base of the ecosystem by ensuring a steady flow of funding for research, development and innovation in healthcare robotics
Description	Several funding organisations specify that for a project to receive support, the funding organisations expect it to generate profits within a foreseeable time frame, such as two years. This is done to prioritise funding for projects that are expected to become commercial successes. The challenge with this requirement is that it excludes large parts of research and innovation in healthcare robotics. This is especially true for patient-near robots, which require the highest level of MDR certification and medical testing and therefore have the longest prospects. But it can also apply to automation solutions, although these typically have a shorter path to profitability. These projects are often not expected to be profitable in the short term. This lack of profitability is due to the special conditions in the healthcare sector and the high demands on technology. This means that projects must be taken to a higher level of technological maturity (between TRL 6 and 9[47]) with a need for continued technology development and adaptation. Therefore, projects often extend beyond what can be supported, and private investors may be equally hesitant. Since the technology area is important for society, there is a need for funding to earmark a portion of their means for healthcare technologies with a longer time horizon. Specifically, organisations can earmark money for technologies aimed at the healthcare sector with less strict requirements for profitability within a few years. The profitability requirement can be maintained, but the time horizon should be extended. They can also go a step further and earmark funds specifically for healthcare robotics. This would be particularly positive for the Southern Danish ecosystem for robotics and could help strengthen Southern Denmark's international status as a leader in the field.
Primary stakeholders	International, regional, and national grantors for development projects, including research and innovation financing funds, programmes, etc.

[47] Technology Readiness Level. https://innovationsfonden.dk/sites/default/files/2019-03/technology_readiness_levels_-_trl.pdf

7.2. International testing environment

Proposal	Establish an international testing environment for healthcare robotics
Purpose	To provide the ecosystem with access to an international testing environment, based on a close dialogue between clinical needs and technological solutions, and knowledge of testing and documentation requirements for healthcare robots. This would create an attractive environment for international experts, companies, and investors, as well as make it easier for hospitals to test technology.
Description	Testing of healthcare robotics is a challenge for both companies and the healthcare system. For companies, it is difficult to get the opportunity to test their technologies and obtain documentation of their potential. For the healthcare system, it is difficult to allocate resources to test new technology in a busy schedule. With the establishment of an international test environment, the resources and technologies for testing of healthcare robotics are brought together. The testing environment should have staff attached and build on existing facilities, as well as seek partnerships with robot companies to make their solutions (hardware and software) available. Therefore, the testing environment should constitute a unified entry point for companies to test robot solutions in as realistic an environment as possible. By gathering existing and new test facilities under one virtual or even physical roof, an international beacon of professional and technical capacity can be achieved. Inspiration can be drawn from, and collaborations can exist within, other environments, e.g., with the environment for surgical robots in Germany.[48] The testing environment can carry out development projects, tasks for customers or house companies' development projects. The testing environment should also support education and training in the use of robots for employees in the healthcare sector. The testing environment can include: • Living Labs: Physical testing facilities that mimic the physical conditions of a hospital. • Digital twins: A digital testing environment that mirrors the physical and IT infrastructure of existing hospitals. • "Real life test" Collaboration with hospitals and institutions in Southern Denmark to test in the environment where the solution is to be applied.
Primary stakeholders	The environment is initially established as a network between hospitals and research and knowledge institutions. Private stakeholders will also play an important role.

[48] https://www.imte.fraunhofer.de/en/Kompetenzfelder/Medizintechnik/Medizinische-Robotik-und-Training.html; https://miroinnovationlab.de/en/home-en/index.html; Olsen, U. K. (2021). "Industry on Campus in Southern Germany." *ICDK Outlook*, München: Innovation Centre Denmark; Olsen, U. K. and Jakobsen, L. H. (2022*).* "Test and Demonstration Facilities in Southern Germany. Inspiration for Denmark." ibid.

7.3. Strengthen counselling for businesses

Proposal	Strengthen counselling for businesses regarding public procurement processes and business cases
Purpose	To promote businesses' interaction with, and ability to market their products to, public buyers by creating greater clarity about e.g., testing and documentation requirements as well as the overall value for the healthcare sector
Description	This proposal aims to create greater transparency and understanding of how suppliers of robotic technological solutions and the healthcare sector can work together. The proposal is not intended to change the rules and guidelines that apply to public procurement, but rather to create clarity about them. The proposal is two-fold and involves the development of: • An illustrative, generic model of the various procurement processes in the public sector. The model should describe how the seller and buyer can engage in constructive processes for delivering robotic technological solutions. The model should highlight, among other things, needs assessment, adaptation requirements, documentation and approval requirements, and decision-making processes. • A concept for the good business case for robotics solutions for the healthcare sector. A business case must be a convincing argument for the value of introducing robotics solutions. In the healthcare sector, the value is not only a question of freeing up personnel, but also functionality, safety, hygiene, impact on, or effects for, staff and patients, etc. Therefore, it is recommended to develop a concept for how the good business case can be prepared, including relevant data sources and calculation methods (such as return on investment and total cost of ownership). The general description can be supported by specific examples of business cases for robotics solutions that can serve as inspiration. This material is initially presented in a report (white paper) but should also be disseminated on a website so that it is accessible. The material should serve to further develop advisory services aimed at developers and suppliers.
Primary stakeholders	Prepared by a knowledge institution together with the Region of Southern Denmark. Stakeholders who could benefit from the material include Erhvervshus Fyn, knowledge institutions, business clusters, and incubator environments.[49]

[49] Se fx: https://ehfyn.dk/content/ydelser/5-gode-raad-faa-succes-med-robotter/1afde7f5-fe67-47cf-9d62-0f147ac59401/; https://www.teknologisk.dk/ydelser/syv-raad-til-naar-du-skal-have-din-robot-ud-i-sundhedssektoren/44473; https://www.sdu.dk/da/samarbejde/startups_og_spinouts/startup-univers/kontakt-sdu-entrepreneurship-labs

7.4. Open IT standards

Proposal	Define IT standards for healthcare robotics.
Purpose	To make it easier for businesses to deliver products that hospitals can integrate with each other, including supporting fleet management
Description	Today, hospitals face a challenge with different robots from different companies operating with different systems. This complicates fleet management. Additionally, robots may require specially customised hardware installations, e.g., to communicate with doors or elevators. If a hospital has multiple different robots in operation, it may need to install several different hardware components in all doors and elevators. Mandating one specific control system or IT language to all supplier companies would be unrealistic and impractical. Instead, we suggest defining a set of standards for IT compatibility and communication protocols that robots must follow. These should be specified in public tenders, as well as in smaller robot purchases. The key is to find the right balance between giving companies the freedom to use the systems they prefer, while also ensuring that hospitals have better opportunities to manage the robots collectively once they are in operation. The specific standards required can preferably be coordinated across the regions (as far as possible) to make it easier for companies to scale their production.
Primary stakeholders	Regional IT, possibly in collaboration with other regions

7.5. Technology forum

Proposal	Create a technology forum for knowledge sharing, market dialogue, and problem-solving
Purpose	To strengthen the dialogue between clinical needs and (new) technological solutions and to initiate development projects to solve immediate technological challenges with significant commercial potential
Description	With the establishment of a technology forum, a stronger bridge is built between research/innovation and the healthcare sector. The purpose is partly to spread knowledge among clinicians about the technological possibilities within robotics, and partly to spread knowledge among robot technicians in companies and research about current clinical challenges. This is about matchmaking between needs, challenges, and technology, which should provide inspiration and possibly lay the groundwork for future development projects. The target group is technology and user specialists and experts from business, research, and the healthcare sector – and potentially investors as well. The proposal is a continuation and development of similar initiatives that have existed in other areas, such as the Fast Track network for material specialists[50] and a series of events for robot startup companies.[51] There are two elements to the initiative: • Matchmaking and network events Regular network meetings or conferences where clinicians present current needs and challenges, and robot technologies present technological possibilities. Experts will ensure the quality and relevance of topics and presentations. • Fast Track A facility for establishing smaller development and innovation projects where companies, the healthcare sector, researchers, and specialists from knowledge institutions can work together to create solutions to (smaller) common technological challenges (demonstration projects) and also projects for individual companies. Experts from knowledge institutions will lead these projects. The technology forum does not need to include both elements, but it would be fruitful to try to support the ideas that arise from the matchmaking with financing.
Primary stakeholders	The technology forum requires an administrative and professional set-up that can be managed collaboratively by a business cluster, university, or knowledge institution.

[50] Danish Technological Institute (2020): Fast Track – Et netværk for materiale specialister. Virksomhedernes vurdering af Fast Track. MADE – Denmark's production closter has further developed the concept: https://www.made.dk/made-fast
[51] See e.g., https://www.odenserobotics.dk/da/events/startup-walk-in-pitch-your-idea-and-get-expert-feedback/

7.6. Strengthen business counselling regarding CE certification for medical devices

Proposal	Strengthen counselling for businesses regarding CE certification for medical devices (MDR).
Purpose	To create greater clarity about testing and documentation requirements in connection with CE certification, so that new robotics solutions can enter the market faster, and to bring resources from international companies into the ecosystem
Description	To enter the market, robotics for the healthcare sector must be CE marked to demonstrate compliance with EU-standardised safety requirements. Medical Device Regulation (MDR) for healthcare technology is divided into three classes depending on the potential harm to the patient. The top two classes require involvement of a notified body to handle certification.[52] In addition, medical equipment's CE marking must be regularly renewed. There is currently no body to notify in Denmark, and even at the European level, access to CE marking of medical devices is a significant bottleneck for the development of healthcare technology. Fortunately, this is changing as TÜV is in the process of becoming authorised. However, even with the establishment of a notified body in Denmark, strengthened counselling on CE certification under MDR would be a significant strength for the ecosystem. The rules are complex, and strengthened counselling could potentially increase the speed at which new technologies are certified. The presence of a notified body in the future is also expected to attract businesses from other European countries. Here, strengthened counselling could support the establishment of stronger ties between international companies and the ecosystem. Counselling could be anchored in the more general counselling for companies presented in the third initiative, but it can also be established separately.
Primary stakeholders	Knowledge institutions and/or business clusters can provide counselling, possibly with support from the Region of Southern Denmark.

[52] https://laegemiddelstyrelsen.dk/da/udstyr/bemyndigede-organer/

7.7. Commercial scaling of development projects

Proposal	Strengthen the focus on commercial scaling in development projects
Purpose	To increase the likelihood that development projects within healthcare robotics result in scalable technology and thus have significant commercial potential for the benefit of both companies and users
Description	Funding bodies behind development projects should place greater emphasis on promoting projects that address generic issues, and thus create solutions that potentially can be widely used in the healthcare sector and sold to more customers than just a single institution. The degree of generality in the issue should be a parameter in the evaluation of development projects. This can be assessed based on: 1. an assessment of the overall need for the technology beyond a single case. 2. opportunities to adapt the technological solution to multiple institutions. The aim is also to encourage the stakeholders driving development projects to have higher ambitions for the use of project technologies. To create a good framework for such development projects, the projects should be anchored more firmly in a follow-up group consisting of stakeholders with a strategic perspective on the development project. In this way, projects will always receive input from persons who have an eye for broad application possibilities and the long-term commercial perspective, rather than just focusing on specific (often technical) issues and applications in a specific context. This proposal also includes a call to strive for larger "flagship projects" rather than very specific issues, as well as to bring the projects to a higher level of technological maturity (between TRL 6 and 9).
Primary stakeholders	International, regional, and national funding bodies for development projects, including research and innovation funding funds, programmes, etc.

7.8. Marketing

Proposal	Strengthen the marketing of Odense as a Robot City with a healthcare perspective
Purpose	To draw greater attention to "Odense Robot City" – including in the healthcare sector – to attract companies and labour from the rest of Denmark and abroad to the ecosystem and thereby strengthen its resource base
Description	Odense's brand as a robot city is already well-known in Denmark and internationally. We propose that this be strengthened with an even stronger international focus and a clearer emphasis on the healthcare sector. Specific marketing of Odense as the centre for "robots for the healthcare sector" would be unique at the European level. Branding serves several purposes. It can attract a qualified workforce in the robotics field, attract internationally leading companies to establish their own departments or invest in Danish companies in Southern Denmark, attract venture capital to help the robotics companies in the area, and attract interest in collaboration from foreign research and knowledge institutions. In short, it can support the continued influx of workforce, capital, skills, and knowledge to the ecosystem. Marketing should be carried out through a range of activities that promote awareness of "Odense Robot City" and the healthcare perspective, such as: • "Odense Robot City" on social media, reflecting the entire ecosystem and what it can offer an external workforce, companies, investors, and potential partners, such as an overview of stakeholders • Attracting international conferences and fairs on robotics or the healthcare sector, including a special PR effort for participants at these events • Advertisements on social media and streaming services targeting students with technical profiles • Large billboards at motorway exits to Odense. For example, "Next exit: Denmark's Robot City" The advertisements can highlight some of the leading robotics companies in the ecosystem and be co-financed by these. A joint campaign could be coordinated by a business cluster to bring together a range of companies. Investor-related stakeholders should also be activated in relation to international marketing and attraction of companies, institutions, workforce, and investors. This could take the form of a more strategic effort with a fixed steering group, so that individual initiatives and delegations are integrated into a more structured framework and involve relevant partners in the ecosystem.
Primary stakeholders	The effort could be coordinated by Invest in Odense in collaboration with the business cluster Odense Robotics, Odense municipality, and/or companies.

7.9. A unified vision for the Southern Danish ecosystem

The eight initiatives address different aspects of the Southern Danish ecosystem's development, and each can strengthen elements of the ecosystem for healthcare robotics. They can therefore be considered as a buffet of ideas with proposals that will target different stakeholders within as well as outside the ecosystem.

However, the initiatives can also be considered a package or menu that can support each other and the ecosystem. The following reflections describe how the proposals can be combined into a unified vision for the ecosystem in Southern Denmark. Such a unified vision will, of course, require significant investments and resources. In return, it has the potential to further revitalise the ecosystem and position it as an international hub for healthcare robotics.

The overall goal of such a revitalisation is to strengthen the conditions for developing and selling robots for the healthcare sector, contributing to some of the major challenges the healthcare sector faces in terms of freeing up labour for care tasks. By developing an attractive environment for robot companies in the healthcare sector, based on the existing industrial environment for robotics, even better conditions can be created for establishing new companies, spinoffs, and attracting companies and capital from outside.

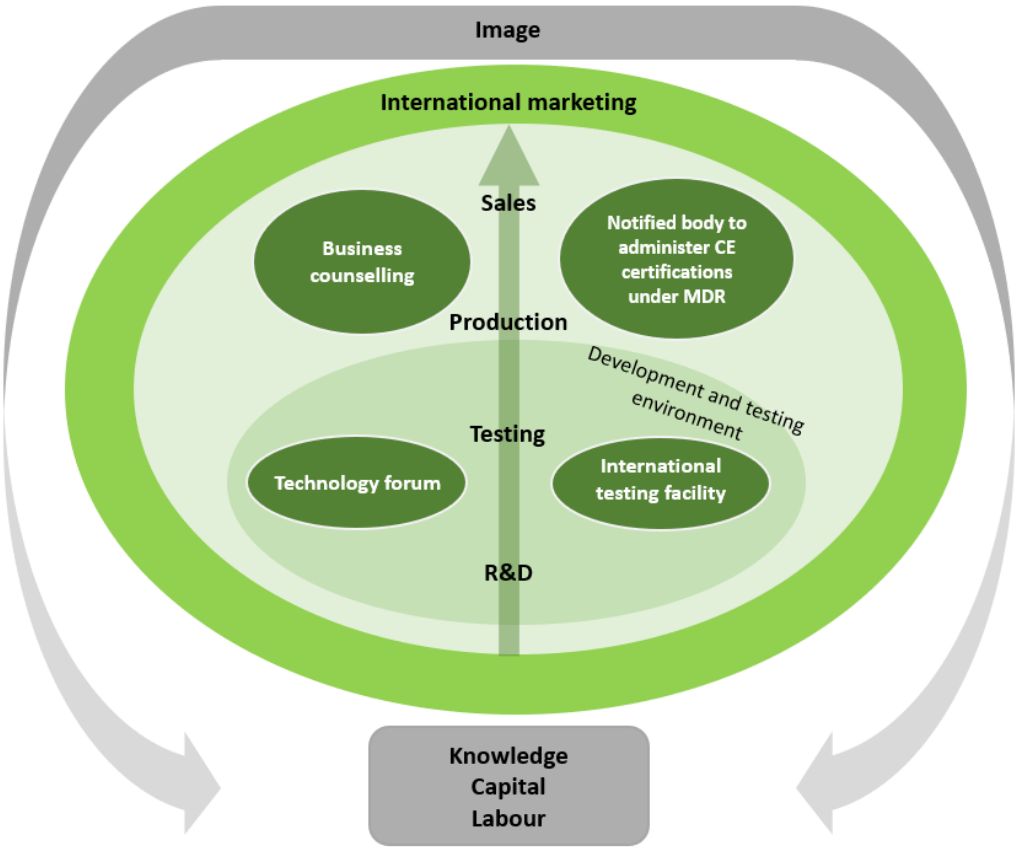
Although "Odense Robot City" is strong today, one must expect increased competition in the future. A revitalisation of the overall ecosystem for healthcare robotics will be a crucial steppingstone to creating an attractive development environment.

With this starting point, we propose a unified vision for the ecosystem – for strong relationships and collaborations among stakeholders – to create the framework for an attractive environment for industrial development.

The overall vision for the ecosystem revolves around the international test environment (initiative 2) and regular events in the technology forum (initiative 5) that match clinical needs with technological solutions and help development projects get off the ground. In addition, there should be access to business counselling (which disseminates knowledge from initiatives 3 and 6), which can thus support the technologies' path to the market. Finally, the environment can support education and training of healthcare personnel, both through individual courses continuing education of clinical staff and as a resource for basic education.

All these activities can be brought together in and around the same physical facilities at the new OUH, SDU and Forskerparken, where the Health Innovation Centre of Southern Denmark and the Danish Technological Institute already reside. This creates a physical hub for the development and testing of healthcare robotics, with the possibility of maximum synergy between the stakeholders involved.

Figure 2. A unified vision for the Southern Danish ecosystem



It is important that this overall development and test environment should be a resource for hospitals in Denmark and internationally. In other words, it should cement Southern Denmark's strong position in healthcare robotics and provide facilities for external collaborators. This process should be supported by extensive marketing of Odense Robot City with a focus on the healthcare sector and target an international audience (initiative 8).

By creating a unified physical powerhouse for healthcare robotics, the development and test environment will maximise the benefits of being an ecosystem (as described in Chapter 4) by becoming a sort of *ecosystem within the ecosystem*. In the development and test environment, stakeholders will be heavily dependent on each other to achieve shared success, it will be populated by different types of stakeholders with different resources and relationships, the geographical proximity will create the best conditions for informal contact and high activity, and the close ties will support mutual understanding between the stakeholders.

So, what are the expected benefits of such a comprehensive development and test environment?

1. The development and test environment will attract resources to Southern Denmark in the form of capital, labour, international companies, and development projects from around the world.

2. The development and test environment will support the development process that will result in new robot technologies that deliver higher quality for patients, save time for personnel in hospitals, and create better working conditions for employees.

3. The development and test environment will release personnel at individual hospitals throughout Denmark by bringing development and testing to one place rather than having testing efforts scattered across many hospitals.

4. The development and test environment will give companies the best conditions for developing, testing, and seeking approval for new healthcare robotics. This will support technological and commercial development in an important area. This overall facility will be particularly helpful for startup companies with limited resources, giving them consolidated access to all the necessary knowledge and testing capacity.

5. The development and test environment will support the education of healthcare personnel in collaboration with robotics companies, so that personnel are best equipped to work with and get the most out of the robots.

6. The development and testing environment will create even stronger links between research institutions, companies, and the healthcare sector to establish the best possible conditions for development, innovation, and knowledge dissemination.

7. The development and testing environment will provide Danish and international investors with opportunities to acquire knowledge about clinical needs and technological possibilities, so they can invest capital in companies with the greatest potential and thereby support the development of solutions that are able to be commercialised.

Realising such a comprehensive development and testing environment will require involvement from many stakeholders and significant investments, including extensive support from grantors. It will also require a strategic leadership effort at a high level in collaboration with private stakeholders. In the startup phase, the Region of Southern Denmark and OUH will play central coordinating roles, and there may be a need to establish a strategic forum specifically focused on this area. It will be critical that the project reaches beyond public stakeholders and involves private companies, knowledge institutions, and business clusters, as well as other hospitals in Southern Denmark, so that the final proposal can create value far beyond the boundaries of Odense.

Realising the full potential of such a large-scale vision requires a strategic leadership perspective that goes beyond each individual stakeholder and their individual agendas. A strategic perspective can be ensured in several different ways and through various organisations. In the ecosystem, there is already a strong network between the central stakeholders. Thus, there is already a good foundation that can be built upon in realising the overall vision for the Southern Danish ecosystem for robotics for the healthcare sector.

8. Conclusion

This analysis has painted a picture of the Southern Danish ecosystem for healthcare robotics in 2023. We have also looked ahead and presented future possibilities for the ecosystem, as well as the development areas that are crucial for whether the ecosystem can create even better conditions for the development and commercialisation of robotics that can enrich the healthcare sector in Denmark and internationally.

The Southern Danish ecosystem has significant strengths to draw on, which will be crucial for its future. The key is therefore to create the best framework for the relationships between the stakeholders in the ecosystem, so they can enrich each other and together develop the robotics solutions that create the greatest possible value for the healthcare system and therefore commercial value for the companies.

It is important to keep in mind that the future of the ecosystem depends on far more stakeholders than just the public ones. The eight initiatives presented in this analysis are therefore not (just) policy recommendations for public stakeholders. They are, likewise, aimed at the private sector, whether it be companies, business clusters, foundations, or others. For the ecosystem to work optimally, cooperation between public and private stakeholders is necessary, and the responsibility for the future of the ecosystem cannot be placed on just one side.

This report's eight initiatives constitute specific steps in directions where the ecosystem could be strengthened. But we also encourage more visionary holistic thinking, where the proposals are seen as a comprehensive project that could have a profound impact on the Danish healthcare system's access to robotics in the future. Seizing this overall vision will require great willingness and many resources from stakeholders within and outside the ecosystem. In return, it could truly put Denmark, and Southern Denmark specifically, on the map for healthcare robotics and be a great help for hospitals as well as for startup companies that have good ideas but struggle with the harsh conditions for new companies that characterise the healthcare sector.

All the strengths, development areas, and initiatives related to international relations are also applicable to the ecosystem's relations with Germany in particular. By making the ecosystem more attractive and visible to international partners, it will also strengthen the conditions for cooperation with relevant German stakeholders and for marketing robot products to German customers. Thus, the initiatives can also bring Southern Denmark closer to Germany.

Today, Southern Denmark has a leading international position in healthcare robotics. This position is not guaranteed, and it is not necessarily permanent. This report has identified areas that need to be addressed for the ecosystem to maintain its position, and we have presented a vision for how the leadership position can be expanded so that the ecosystem can achieve a new and higher level of impact nationally and internationally.

9. Appendix. List of interviewees

Name	Title	Organisation or company
Jan A. Toft	Development Manager	Sygehus Sønderjylland
Søren Andreas Just	Chief Physician, Lecturer, Founder	OUH Svendborg, SDU and ROPCA
Ditte Korsager	Business Manager	Vonsildhave, private nursing home, Attendo
Søren Udby	Managing Director	Centre for Clinical Robots, OUH
Jens Kristian Damsgaard	Executive Partner	Science Ventures Denmark (part of SDU)
Michael Tandrup	Founder and Partner	NordiC Eye
Rasmus Festersen	Investment Manager	Invest in Odense
Lars Baun	Private Investor	Private investor
Søren Elmer Kristensen	Project Director	Odense Robotics
Mikkel Christoffersen	Director	Odense Robotics
Karen Lindegaard	Senior Consultant	Danish Life Science Cluster
Sarah Niemann	International Affairs Manager	Life Science Cluster Hamburg and Schleswig-Holstein, Life Science Nord
Lone Jager Lindquist	Director	PTR Robotics (a part of Blue Ocean Robotics)
Julie Dalsgaard	Director	Lifelife Robotics
Per Juul Nielsen	Director	UVD Robots
Mathias Vinter	Head of Holo Air	Holo
Lasse Thomsen	Director	LT-Automation
Sune Bertelsen	Channel Development Manager	Universal Robotics
Rasmus Smet Jensen	VP Marketing and Strategy	MIR
Peter Bøgh Sørensen	Vice President, responsible for healthcare	Linak
Henrik Danevig-Anker	Director	Gibotech
Eva Tansem Andersen	Sustainability and Development Manager	Abena
Thiusius Rajeeth Savarimuthu	Professor, Founder	SDU and ROCPA
Mads Thorup Langelund	Senior Consultant	UCL
Philipp Rostalski	Professor and Director	Fraunhofer Research Institution for Individualized and Cell-Based Medical Engineering and Institute for Electrical Engineering in Medicine
Louise H. Godtfredsen	Specialist advisor	Health Innovation Centre of Southern Denmark

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