

Technology Development Roadmap for Medical Robotics in Thailand

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Abstract--Medical robotics plays an increasingly important role in healthcare as it has clear potential for improving diagnostics and therapeutic capabilities, lowering the number of medical errors and improving the overall quality and cost effectiveness of Thailand's health care delivery system. It has been predicted that in 2025, the size of the robot market will reach US\$ 66.4 billion. Thailand's advancement in medical robotics is critical for improving the capabilities and competitiveness of the country's healthcare system. As a result, the Thailand Center of Excellence for Life Sciences (TCELS) and the Ministry of Science and Technology, has established the advanced medical robotics program, under the flagship policy of the Ministry of Science and Technology, to improve the strength and competitiveness of the country both economically and socially. This paper outlines the development of a Technology Roadmap (TRM) for the Center of Advanced Medical Robotics with the aim of developing medical robotics and services, enhancing product standards and developing human resources.

I. INTRODUCTION

The Thailand Center of Excellence for Life Sciences (TCELS) and the Ministry of Science and Technology, have established an advanced medical robotics program, under the flagship policy of the Ministry of Science and Technology. The initiation of this program is the result of a large government initiative to strengthen the country's competitive position in the global community. To this end the Thai government has designed a strategy that will let every Ministry develop their own flagship project for the period of 2013-2018.

The medical robotics project started in the year 2013. Its objective is for Thailand to be the leader in research and development and to build medical robotics in Asian countries. The development project is divided into 3 main parts: (1) build a competitive medical robotics industry, (2) Develop people and career path, (3) Develop medical robotic capabilities with universities in Thailand.

In Thailand exists a large inequality between the rich and the poor and access to basic health care is a big problem for many. Especially the rural population is in need for better access to medical services and building technological capabilities is expected to address this problem. Also with the pressure of an aging Thai population [1] the amount of elderly and age related illnesses is bound to rise. The Thai government has recognized the need to invest in medical robotics to reduce healthcare related expenses for the country in the areas of diagnostics, treatments and medical services. With the medical robotics program the government hopes to

improve the quality of life not only for handicapped people but the overall population of Thailand.

A. Medical Robotics

A healthcare process can be divided into detecting symptoms, diagnosing diseases, treating diseases and preventing diseases. Medical robotics can provide direct and indirect patient care that will decrease medical errors by improving accuracy in screening and monitoring. Employing medical robots to support the activities of healthcare professionals will remove some of the workload and improves their productivity, enabling them to provide a better personal service to the patient.

Robots in general should be capable of sensing, cognition and actuation. The sensing part of a robot's capability is important for the machine to perceive and collect data from its environment. Cognition processes the collected data, makes decisions and then enables the robot to interact intelligently with its environment. The actuation capability of the robot represents its ability to move around and manipulate parts of the environment, based on the processed data (e.g., operating a mechanical limb). Medical robotics can be dividing into three major categories:

1. Treatment Robots:

Robots used in the operating room to screen, scan or assist in the procedure. Robots used as part of the patient rehabilitation.

2. Support Robots:

Robots that can help handicap patients, elderly or robots that can assists healthcare professionals to improve their skills (e.g., robotic exoskeletons, training robots, etc.).

3. Medical Service Robots:

Robots that provide healthcare services in the hospital or at a patient's home (e.g., welcome robot, pill dispensary robots, etc.).

Medical robotics plays an important role in improving a healthcare system and robots will be able to assist in all stages of the healthcare process making it more effective and efficient. Besides improved quality of the healthcare system in terms of access, diagnosis and treatment, medical robots can also facilitate the development of capabilities by assisting in R&D or training.

B. Medical Robotics Industry

The Japan Robotics Association [2] predicts that the size of the global robot market will reach US\$ 66.4 billion in

2025. According to the International Federation of Robotics (IFR) medical robotics is only a small portion of this market, but the segment is growing fast and observes the highest value per unit sold [3]. The main hindrance seems to be the regulation for medical robots since safety is critical to human life.

Although the global medical robotics industry is strong and rises fast the local Thai industry is still in its infancy and is largely dependent on government support. Government support is particularly needed in the areas of determining regulations and defining standards for medical robots. A few of the country's academic institutions have picked up on this trend and offer studies in the field of Bio-Medical Engineering, which focuses on how medical science and engineering can be integrated to benefit the society. The program can be used as a stepping stone to build the countries capabilities in the field of medical robotics, since the field is situated on the intersection of these two areas.

To provide ample government support for the medical robotics program the ministry of science and technology has commissioned the Thailand Center of Excellence for Life Sciences (TCELS) with the challenge of mediating between the various government and non-government stakeholders. Tasked with this challenge TCELS decided to develop a Technology Development Roadmap for Medical Robotics in Thailand. The purpose of the roadmap is to strengthen Thailand's position in the medical robotics industry and to build linkage throughout the network of stakeholders to facilitate cooperation. The roadmap focuses on the development of medical robotics products and services in Thailand.

II. TCELS ROADMAPMING PROCESS

To become more competitive in the global medical robotics industry, Thailand needs to connect its capabilities in robotics to the needs of the society. For that purpose TCELS has initiated the Medical Robotics Program under the flagship policy of the Ministry of Science and Technology in January 2014. Roadmapping is an increasing popular tool to link the capabilities of an organization with the requirements or needs of the market over a certain time horizon [4, 5]. Being able to visualize connections among various streams of capabilities (e.g., R&D projects, Technologies, Human Resources, Budgets, etc.) and requirements (e.g., market needs, trends, policies, societal needs, etc.) can enable an organization to communicate more efficiently and synchronize strategies and directions among its numerous units [6]. Based on the audience and communication need a roadmap can display different levels of details [7]. Internally the roadmap will be used as a guide to provide an overall direction for TCELS and how to make most efficient use of their resources. With an established direction TCELS is then

able to provide linkages to its partners and synchronize directions, goals and targets among them. Each year TCELS needs to write an action plan as part of the proposal to obtain funding from the government. As part of executing the roadmap TCELS can develop their action plan and manage their project portfolio more effectively.

One of the major challenges to a project that tries to combine the capabilities of several government and private institutions, is communication and a common direction. TCELS initiated the development of a roadmap to facilitate and mediate the collaboration among several government and private organizations. The overall purpose of the medical robotics roadmap is to enhance Thailand's competitiveness by strategically aligning capabilities of various institutions. The medical robotics roadmap intends to achieve three main goals: (1) The development of medical robotics products and services, (2) The enhancement of product standards and (3) Development of human resources.

A generic Roadmapping process can be classified into three stages initiation, development and integration, where each come with their own challenges, goals and targets [5, 8]. To effectively manage each stage of the process TCELS needs to customize the process based on its specific roadmapping purpose and goals [9, 10] determine the right people to execute and support the process and specify what kind of information is needed to populate the roadmap [11]. In February 2014 the initial medical robotics team kicked-off the project to develop a medical robotics program roadmap. During the meeting the team discussed the roadmap development process, determined the key players in the medical robotics industry, information needs, as well as designed an appropriate roadmap development process and architecture. As a result an action plan was developed that outlined the schedule of the roadmap working group meetings and the brainstorming session. Figure 1 below summarizes the roadmap development framework used by TCELS.

The initial medical robotics team of TCELS decided to use a workshop based approach to develop the medical robotics roadmap [12] and a layered design of the roadmap document [9, 13]. A workshop based approach is more efficient to collect data from a large group of experts than individual interviews, since individuals are able to engage in constructive discussions about a certain topic. The initial roadmapping team decided that the roadmapping workshops should be designed in a round table discussion with brainstorming sessions to generate ideas and discuss challenges.

In Jun 2014, the initial team finalized the list of key players in the local medical robotics industry and formed the roadmap working group with participants from 11 of the main stakeholders of the project (Table 1). Once the roadmap working group was formed the roadmap development could begin.

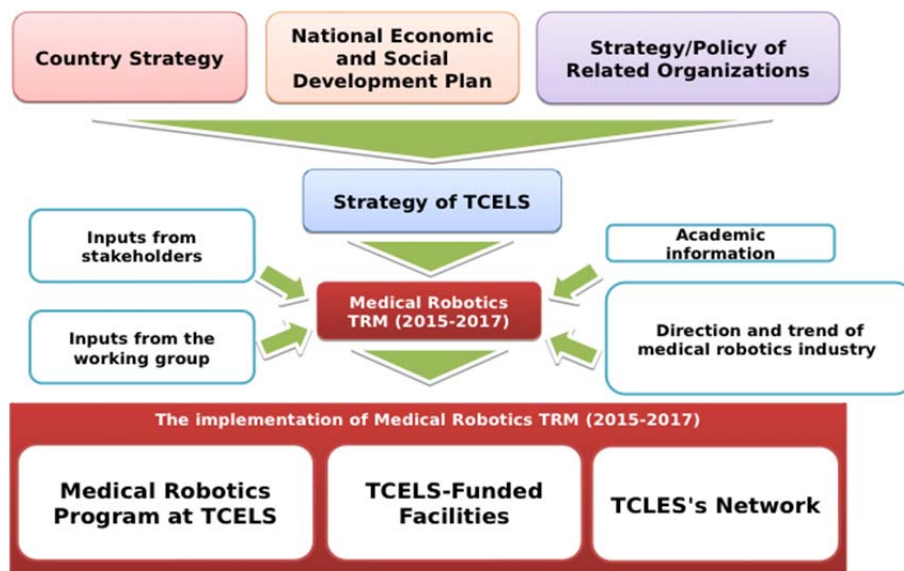


Fig. 1. TCELS's Roadmap Development Framework

TABLE 1
KEY STAKEHOLDERS OF THE MEDICAL ROBOTICS PROGRAM ROADMAP

Organization	Role	Roadmap Working Group
<i>Medical Organizations</i>		
Health Systems Research Institute (HSRI)	Support medical research, especially medical devices that will be embedded in human bodies.	✓
National Health Security Office (NHSO)	Public Organization to respond to the public good management system	✓
The Medical Council of Thailand	Regulate and monitor medical practice in Thailand	
Thailand Nursing and Midwifery Council	Regulate and monitor nursing and midwifery practice in Thailand	
Siriraj Hospital	A university hospital	
Ramathibodi Hospital	A university hospital	
Sirindhorn National Medical Rehabilitation Centre (SNMRC)	Provide rehabilitation services	
The Royal Thai Army School of Nursing, Midwifery, & Public Health	Educate, train and prepare nurses at baccalaureate level. Also develop and conduct research in nursing and in other health-related services	
<i>Private Organizations</i>		
CT Asia Robotics	A software company developing an elderly care robot named "Dinsow"	✓
Supreme Hitera, Co. Ltd.	A big company who earlier mainly imported healthcare and medical products. Now, they started to develop their own automatic drug dispensing system, in collaboration with TCELS and KMUTT.	
The Federation Of Thai Industries	The private sector administrative juristic person to serve as the core organization and also as the centre for all Thai industries in the kingdom. It is a non-profit organization with the main duties of promoting and supporting the industry focusing on both developing sustainable growth for all industrial operations in the country	
<i>Industrial Development Organizations</i>		
The office of Industrial Economics	A public organization responsible for integrating and implementing industrial development policies, plans and strategies	
Plastics Institute Of Thailand	A public organization responsible for collaborating with the government, academic and private sector to support Thai plastics industry.	

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TABLE 1
KEY STAKEHOLDERS OF THE MEDICAL ROBOTICS PROGRAM ROADMAP

The Board of Investment of Thailand	The principal government agency for encouraging investment	
<i>Regulating Organizations</i>		
Thai FDA	Regulate health-related products	✓
<i>Testing Facilities</i>		
Electrical and electronic product testing center (PTEC), NSTDA	Provide testing and calibration services	✓
<i>Policy Makers and Budget Management</i>		
Thailand Advanced Institute Science and Technology (THAIST), STI	Create network for academic and research collaboration to support human resource development	✓
Bureau of Thai Budget	Manage government budgets	
<i>Scientific Research and Innovation Organizations</i>		
Thai Robotic Society (TRS)	A group of researchers for academic collaboration on robotic research	
Thailand Institute of Scientific and Technological Research (TISTR)	A public scientific research organization (quite similar to NSTDA)	
National Science and Technology Development Agency (NSTDA), Thailand	A public scientific research organization (quite similar to TISTR)	
National Electronics and Computer Technology Center (NECTEC), NSTDA		
National Innovation Agency (NIA)	A public organization responsible for facilitating innovation development in Thailand, both in terms of making improvements and pioneering new initiatives	
<i>Universities</i>		
Asian Institute of Technology (AIT)		✓
Mahidol University		✓
Sripatum University		✓
King Mongkut's University of Technology Thonburi (KMUTT)		✓
King Mongkut's University of Technology North Bangkok (KMUTNB)		✓
Chulalongkorn University		
Kasetsart University		

After initial meeting of the medical robotics team at TCELS, the Roadmap Working Group conducted three workshops over a period of three month to brainstorm and develop a first-cut roadmap. At the end of October 2014 TCELS organized a large brainstorming session to finalize the first-cut medical robotics roadmap with over 85 participants from all 29 organizations involved with the program. At the beginning of 2015 a final draft of the medical robotics roadmap was generated, ready for a final revision by the Roadmap Working Group in May 2015.

Table 2 summarizes the objective(s), activities and results of TCELS roadmapping process over the six workshop sessions.

The workshop based roadmapping process allowed the roadmapping team to incorporate the feedback and revisions of each workshop into the roadmap. The final version of the medical robotics roadmap can now be used to communicate strategic goals and targets throughout the network of key stakeholders. With a unified direction each stakeholder can then adjust their own operations to synchronize their development with the medical robotics roadmap.

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TABLE 2
SUMMARY OF THE ROADMAPPING PROCESS

<i>Workshops</i>	<i>Objective(s)</i>	<i>Activities</i>	<i>Results</i>
Roadmap Working Group Meeting #1	<ul style="list-style-type: none"> - Describe TCELS's role in the medical robotics program and the purpose of the roadmap to the program - Define the objectives of the program and specify the focus of the roadmap - Present some background on medical robotics (current market situation, and technology) - Discuss the structure of the roadmap and the development process 	Roundtable Discussion	<ul style="list-style-type: none"> - A lot of suggestions and comments from the working group - Should be more specific about the situation in Thailand e.g., inequality, problem with healthcare accessibility in the rural area - More studies on the standards for medical robotics needed - The roadmap should be more focused, i.e., should clearly specify the product and timeline that will be supported. - Problems, challenges and solutions for the medical robotics industry in Thailand - A lot of comments about the roadmap content and structured
Roadmap Working Group Meeting #2	<ul style="list-style-type: none"> - Discuss the updated roadmap structure - Discuss the current situation of the medical robotics industry in Thailand - Addressing issues regarding conflict of interests - Discuss the organization of the main brainstorming session and who should be invited 	Roundtable Discussion	<ul style="list-style-type: none"> - More comments on the roadmap structure - Information from FDA about rule and regulation of medical robotics in Thailand and other countries - Initial list of key products and services that the roadmap should focus on - Comments on how to resolve the conflict of interests - A lot of comments on how the brainstorming session should be organized
Roadmap Working Group Meeting #3	This one mainly deals with the detail of the brainstorming session organization.	Planning and Organizing	Detail event plan for the main brainstorming session.
Main Brainstorming Session with all Stakeholders	<ul style="list-style-type: none"> - Obtain comments from all groups of the invited stakeholders (i.e., government agencies, industry, academia, users and consumers) - Understand the role of related government agencies and how to collaborate - Discuss the capabilities of Thailand (i.e., existing research and product development projects) - Discuss the needs that have not been covered by existing work (e.g. robots to train doctors) - Discuss the direction and sequence of product development. E.g., the initial focus should be on robots that are simple, cheap, portable, low risk and do not involve a lot of regulation - Discuss problems and solutions for medical robotics and their uses in Thailand 	Roundtable Discussion Robotics Exhibition	First Draft of the complete medical robotics program roadmap
Medical Robotics Team Meeting	Discuss the first draft of the roadmap and make adjustments	Team Meeting	Final draft of the medical robotics program roadmap
Roadmap Working Group Meeting #4	Presented the final draft of the roadmap and obtain feedback to revise it	Roundtable Discussion	Final version of the medical robotics program roadmap (Fig. 2)

III. TCELS MEDICAL ROBOTICS PROGRAM ROADMAP

One of TCELS functions is to facilitate the development process of medical robotics produce and services. Key to this task is the ability to mediate between the various stakeholders of the program. The program involved the collaboration among 29 organizations from the government and private sector. TCELS objective for the program is to provide a unified direction for all stakeholders. One of TCELS major challenges is to ensure the commitment of all stakeholders to

the program, even though the organization has no means of enforcing any plans with the various stakeholders. To face this challenge, the CEO of TCELS suggested the development of a roadmap in January 2014, which would involve all the stakeholders of the program. The aim of the roadmap was not only to better plan and support their activities, but also to build commitment and synergy among the stakeholder.

A key factor for TCELS's roadmapping process is to develop a roadmap that is consistent with country strategies National Economic and Social Development plan and

strategies and policies of department and industry trends of medical robotics in order to drive an action plan to develop medical robotics technology.S

The medical robotics program is separated into short, medium and long term goals. **Short term goal:** The first 3 years (2015-2017) are mainly aimed at developing the basic structure and personnel of the country, as well as building a collaborative network between the government and non-government organizations. This period will also yield prototypes as part of the product development, to be ready for the clinical trial stage. **Medium term goal:** The development of medical robotics products and services will continue over a period of 4-5 years (budget year 2018-2019) and the main focus during this time will be on clinical trials and commercialization. **Long term goal:** In the long-run the medical robotics program will not only continue building their capabilities and R&D efforts to create and commercialize medical robots and services, but also try to establish a global market position. However, the initial stage of the medical robotics program is to develop a medium term roadmap with specific goals as shown in Table 3.

TABLE 3
GOALS OF THE MEDICAL ROBOTICS PROGRAM ROADMAP

1. The development of medical robotics products and services:

- Provide support for industrial R&D and commercialization
- Provide research funding for prototype development
- Provide funding for expanding the usage and acceptance of commercial-ready products and services
- Transfer technology to public and private sectors

2. The enhancement of product standards:

- Provide initial consultation and support for product testing and certification
- Organize trainings on relevant standards and product development

3. Human Resource Development:

- Stimulate the development of medical robotics related programs, courses, trainings and hands-on workshops
- Support activities that help enhance the students' and workers' capabilities

The overall aim of the medical robotics program is to build a collaborative network that can develop the local medical robotics industry and strengthen the country's global position in developing and commercializing medical robots and services. One of the reasons to develop a Technology Development Roadmap is to study technical information about medical robotics research and technology, industry trends and the current situation of the local medical robotics industry. The roadmapping process of TCEL will also help the stakeholders to determine the strength and weakness of the industry, as well as define obstacles and knowledge gap to the development of medical robotic products and services. In addition the medical robotics roadmap will assist the government in setting overall policies for integrating the capabilities of the various stakeholders in the industry. As a

result the government can then assess the current situation and target its support more specific and effective.

The roadmap working group has designed the architecture of the roadmap in three main layers designated as impact, key achievements and resources (Figure 2). The team has identified two key market drivers (1) aging population and (2) globalization of health care creating several needs that can link directly to the key achievements. One of the major motivations for the Medical Robotics Program is Thailand's aging population. At present Thailand has a population that is aged above 60 years of about 9.5 million or 14% of the entire population. According to a study in 2013 [1] the number of elderly will more than doubled to 20 million by the year 2033 or 30% of the entire population. With age related problems the elderly will account for a large segment of the healthcare industry. Most common problems related to age are for example the deterioration of muscle, ligament, joints, bone, brain cell, aortic stenosis, etc. that can lead to disabilities and need for permanent supervision and care. Thailand's reputation as a medical tourism destination is growing and it is expected that the number of healthcare tourists will surpass 1 million [14]. Over the past years, the number of healthcare travelers heading into Thailand has increased by about 13% per annum [15]. Given this trend, a focus on improving the healthcare system by supporting the development of medical robotics can build Thailand's competitive position as a healthcare destination.

The roadmap working group approached the development process with a technology-push mind set aimed at commercializing medical robotics products and services. Based on this approach the working group specified three strategic targets of the Technology Development Roadmap as Prototype Development, Clinical Trial and Commercialization. Because of the invasiveness of medical robotics the government is emphasizing the importance of developing test standards and regulations as part of the Clinical Trial target. Specifying the link between technology and patient and obtaining FDA approval are crucial, since human life is in direct or indirect contact with the developed technology. To this end a fully functioning prototype is necessary before proceeding with the clinical trial. Commercialization of the technology is possible, only if the prototype passes the clinical trial.

Impact: Because of the affect from these two main drivers, Thailand is expecting a sharp increase in the local need for healthcare related services, products and technologies. With the development of medical robots supporting the needs for healthcare, the roadmapping team aims to make improvements in the quality and cost efficiency of health related products and services. Moreover, medical robotics will reduce medical errors, add more diagnostic capabilities and offers new therapy choices that are less invasive and have fewer side effects.

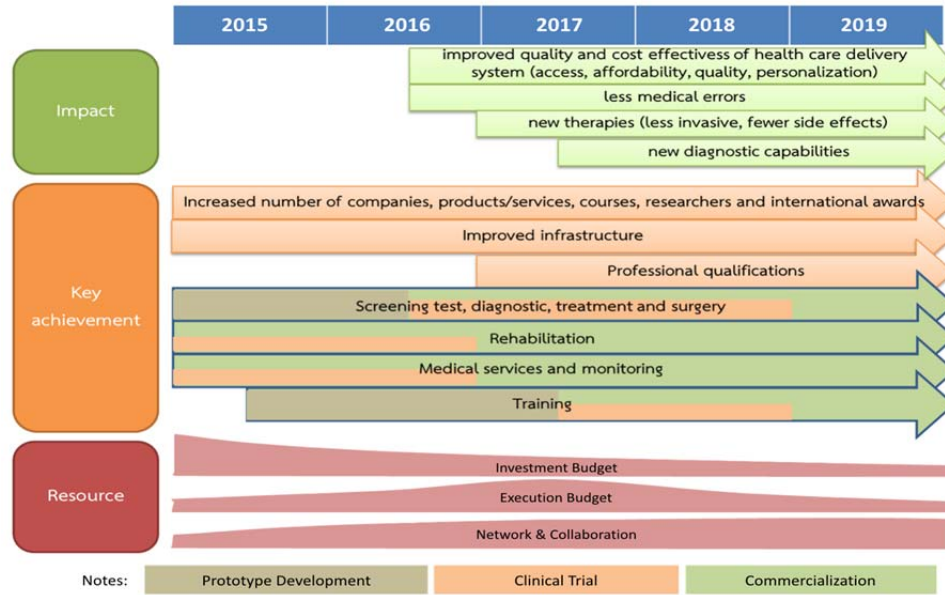


Fig. 2. TCELS Medical Robotics Program Roadmap

Key Resources of the roadmap are classified into three separate groups. *Investment Budget* is most crucial in the early stages of executing the roadmap to lay the foundation and structure to build the countries capabilities. Adding facilities, tools and machinery to support the development of medical robotic products and services. After the initial foundation is laid the *Execution Budget* is of more importance as expenditure into prototyping and clinical trials is an essential step to commercialization. With standards set and tested the extensive Network government and non-government organizations will *collaborate* on commercializing the products and services that past the clinical trial stage.

Key Achievements: The product development of medical robots will focus on four broad categories to support the healthcare system in Thailand (Figure 3). Each hospital operates with mostly standardized processes for diagnostics, treatment and rehabilitation, in which medical robots can find

various applications with direct or indirect contact with the patient or healthcare professional. Development of medical robotics will involve invasive technologies that can assist treatment and surgery, as well as non-invasive technology to support diagnosing diseases or monitoring patients. Other medical robots can assisting with patient care (e.g., facilitating the rehabilitation of patients after a serious illness or procedure). Besides supporting diagnostics, treatments and rehabilitation, medical robots can also find uses in the capability building of the healthcare professionals via medical training robots or support basic operations of the hospital (e.g., medication dispensing system). Anticipating a sharp increase in the elderly population it is necessary to develop robots that can provide or support medical services and assist in the monitoring of patients. Medical technology needs to evolve in order to maintain and restore health outside of the hospital.

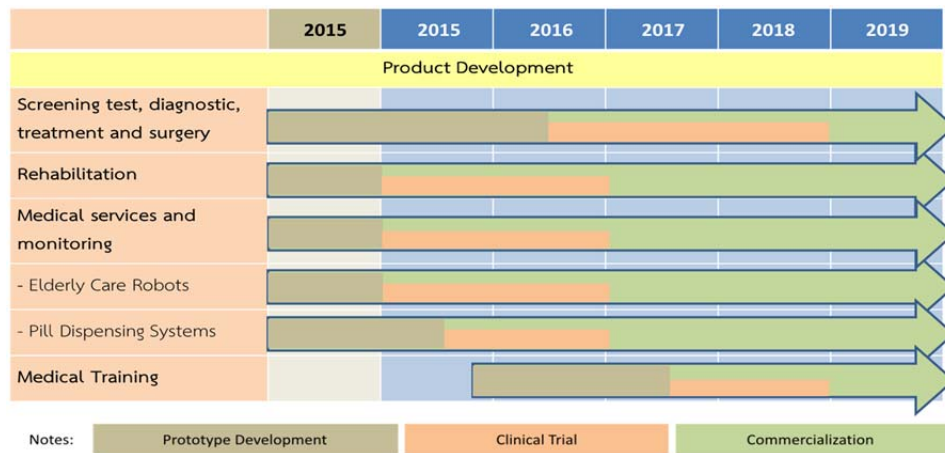


Fig. 3. Key Achievements: Product Development

In the short-term the key achievements are aimed at developing functioning prototypes and complete clinical trials for medical robots supporting rehabilitation and provide medical services and monitoring functions. The main driver behind this product development plan is to support the aging population of the country. In the medium-term the medical robotics program will shift its focus on technology that can be used for diagnostics and treatments. In the long-run the program aims at the development of robots that can assist building medical skills and capabilities.

With the roadmap development complete the medical robotics team from TCELS is put in charge of executing and maintaining the roadmap. Executing the roadmap means to follow the product development plan and then mediate and facilitate collaboration among the stakeholder organizations to deliver their respective parts in the development process. The roadmap specifies the goals and projects of what needs to be accomplished each year. To maintain the roadmap the medical robotics team needs to monitor the overall progress of the roadmap. TCELS has scheduled an annual revision of the roadmap and its strategic targets, based on the current situation.

IV. DISCUSSION

For TCELS the Technology Development Roadmap for medical robotics not only provides a direction, but also helps the organization to identify and prioritize projects to support. For the stakeholders of the medical robotics industry the roadmap gives a unified direction and helps all organizations to synchronize their individual objectives and resources. The roadmap also serves as a master plan for the medical product development in the industry, on which the stakeholder organizations can base development of their project portfolio and action plans. Combining the countries resources and focusing them towards a unified goal will benefit the entire medical robotics industry and its competitive position in the global market. Allocating the country's resources more efficiently will help Thailand to be more self-sufficient with their own technology development efforts.

A. Lessons Learned

One of the best features of the roadmapping project was the round table discussions with brainstorming sessions. The workshop based approach to roadmapping was not only useful for the roadmap development stele, but successfully provided a synergy between robotics researchers and users (i.e. doctors and nurses). Conducting roundtable discussions with cross-functional teams proves to be effective to share knowledge and experiences about medical robotics needs and uses. Obtaining information about the needs and requirements of the users helped the researchers to understand what is possible and which capabilities are needed to provide the right medical robotics products and services. For example, training robots for the healthcare professionals

to build their skills were only included in the roadmap after researchers and users were able to share their ideas.

However, the main brainstorming session included all stakeholders and with over 85 participants was difficult to facilitate. The challenge in facilitating such a large group is to keep conversations on topic and motivation up. Engaging all participant in constructive discussions is an important aspect of a brainstorming session.

Suggestion that address these issues are:

- Splitting the brainstorming sessions into multiple smaller ones for more efficient facilitation
- Enhance the process and criteria to identify participants for each session
- Develop a process to assess and build commitment prior to the sessions

B. Future Plans

At present, the medical robotics roadmap developed by TCELS focuses only the local Thai market and future work could extend the scope of the roadmap to not only include the global markets but also link the roadmap to other robotics research labs around the world. Testing of developed medical robotics technology is vital to satisfy the safety standards required by the healthcare community. The development process of the current roadmap did not include the use and need of testing facilities in greater detail. Product development projects of the roadmap will need a connection to appropriate testing facilities and processes to complete their development. Demand and supply of experts in the field of medical robotics as part of the capability layer is still missing and should be included in a future version of the roadmap. Access to knowledge capabilities that are needed for the R&D of medical robotics technology is vital for the success of the program.

As a part of the Thai government TCELS is not in the position to enforce the execution of the roadmap with all the stakeholders. Most of the stakeholders of the medical robotics program are independent government and non-government organizations that have their own goals and targets. However, as a mediator TCELS will communicate on what the organization will focus on and provide support for. Unfortunately there is no guarantee for a successful execution, but TCELS is confident that with effective communication about prior agreed directions each stockholder will be able to execute their own projects that are part of the medical robotics roadmap.

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