

Feasibility Study of Portable Spirometer Development



Mrs. Chawanrat Trekarjanavong

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ชวัลรัตน์ ตริภากัญจนวงศ์ : การศึกษาความเป็นไปได้ในการพัฒนาเครื่องมือตรวจวัด
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Peak flow meter เป็นอุปกรณ์ที่ WHO และ GINA แนะนำให้ผู้ป่วยโรคหอบหืดใช้เป็น
ประจำ เพื่อสังเกตอาการของผู้ป่วย และทำให้ผู้ป่วยสามารถรับมือกับการกำเริบของโรคได้อย่าง
ถูกต้อง Peak flow meter เป็นอุปกรณ์ที่มีขนาดเล็ก พกพาง่าย และมีราคาไม่แพง สามารถวัด
สุขภาพปอดออกมาเป็นตัวเลข คือ ค่า PEFr เมื่อเทียบกับ Spirometer ซึ่งเป็นเครื่องมือ
ตรวจวัดประสิทธิภาพปอดที่ใช้ในโรงพยาบาล Spirometer สามารถให้ข้อมูลเกี่ยวกับปอดได้
ครบถ้วนกว่า แต่ก็แลกมาด้วยขนาดของตัวเครื่อง ซึ่งมีขนาดใหญ่ ไม่สามารถเคลื่อนย้ายได้ง่าย
ผู้ป่วยจึงต้องเป็นฝ่ายเดินทางไปโรงพยาบาลเพื่อใช้งาน งานวิจัยชิ้นนี้จึงมีจุดมุ่งหมายเพื่อ
ทำการศึกษาความเป็นไปได้ในการพัฒนา Spirometer แบบพกพา โดยมีการศึกษาคุณสมบัติที่
ผู้บริโภคมีความเห็นว่าควรมีในอุปกรณ์ และราคาที่ผู้บริโภคยอมรับได้ รวมไปถึงมีการศึกษา
ความเป็นได้เชิงพาณิชย์ในประเทศไทย จากการศึกษาพบว่า ผู้บริโภคชาวไทยให้ความสำคัญ
เป็นอย่างมากกับสุขอนามัยของการใช้อุปกรณ์ รองลงมาเป็นการให้ความสำคัญถึงคุณสมบัติที่
เกี่ยวข้องกับความสะอาดของอุปกรณ์ เช่น สามารถถอดชิ้นส่วนเพื่อเปลี่ยน หรือ ทำความ
สะอาดได้ โดยผู้บริโภคยอมรับราคาได้ไม่เกิน 1,000 บาทต่อชิ้น เนื่องจากมีประชากรจำนวนมาก
เป็นผู้ป่วยโรคหอบหืด หากสินค้านี้ได้ออกสู่ตลาด คาดว่าจะทำให้เกิดความสะดวกสบาย
กับผู้ป่วยโรคหอบหืด และนำไปสู่การใช้อุปกรณ์อย่างสม่ำเสมอ ซึ่งจะช่วยให้แพทย์ได้รับข้อมูลที่
ครบถ้วน และสามารถปรับเปลี่ยนการรักษาให้สอดคล้องกับอาการของโรคได้ดียิ่งขึ้น แต่
เนื่องจากผู้ป่วยยังขาดความรู้ ความเข้าใจในความสำคัญของการตรวจสุขภาพปอด จึงอาจจะ
ต้องมีการให้ความรู้เพิ่มเติม เพื่อให้การนำสินค้าออกสู่ตลาดประสบความสำเร็จ

สาขาวิชา	ธุรกิจเทคโนโลยีและการ จัดการนวัตกรรม (สห สาขาวิชา)	ลายมือชื่อนิสิต
ปี การศึกษา	2564	ลายมือชื่อ อ.ที่ปรึกษาหลัก

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The peak flow meter is suggested by WHO and GINA for daily use by asthma patients in order to monitor symptoms and manage exacerbations. Even though the peak flow meter is compact, affordable, and portable, it only provides PEFr information. In comparison, the spirometer delivers more thorough lung information. However, it is expensive and difficult to carry, especially the conventional spirometer used in hospitals. The patient must visit the hospital to use it. This research aims to study the functionalities requires for developing the portable spirometer, targeted user and acceptable price in Thai market. Users place a high value on hygiene; hence, the device must be easily detachable in order to replace or clean its components. The portable spirometer should not cost more than 1,000 Thai Baht. With a device that is easily portable and monitors with the same accuracy as a spirometer, the patient may carry it without burden or difficulty. This will allow patients to check their lung function regularly. As a result of having complete information, the doctor will be able to effectively monitor the patient's status and alter the treatment. The size and market trend of this lung monitoring device comprises a worldwide market with a large number of respiratory patients. However, knowledge of lung monitoring devices is minimal on the Thai market. The significance of spirometry should be conveyed to the users.

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Academic	2021	Advisor's Signature
Year:	

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1. Introduction

This chapter described the project's background, the purpose of the research, and the scope and limitations of the investigation. In section 1.4, the definition of the essential information is provided. Following this, the research procedures and projected outcome are described.

1.1. Background and Importance

Asthma affects millions of Thai people each year, especially in rainy season (ALLWELLHEALTHCARE, 2021), and without prompt treatment, asthma can be fatal. According to the Thai Asthma Council (TAC), asthma is found in 7% of the Thai population and causes more than 2,000 deaths per year. Asthma is a chronic disease that can be controlled and avoid fatal conditions if the patients are regularly monitored and treated. Unfortunately, only 30% of asthma patients can access treatment (workpointTODAY, 2018). Combining with the COVID-19 pandemic, which also affects the respiratory system, a self-monitoring device could help people examine their health condition and prevent the disease from developing to a severe stage. Furthermore, the collected data can also be analysed once the patient requires medical action.

1.2. Objective

- 1.2.1. To collect users' needs and expectations for the newly developed Spirometer.
- 1.2.2. To analyse demand and price that is acceptable and suitable for Thai market.

1.3. Scope and Constraint

The study aims to uncover the needs, trends, and demands for the fundamental lung diagnosis device in Thai market. The result of the study will be summarised into

required functionalities and a range of acceptable prices, which will be used to develop the system, including hardware and software for Thai nationals.

1.4. Definitions

1.4.1. Spirometry

Spirometry is a diagnostic test to measure lung capacity, often used to diagnose asthma and other respiratory diseases (Theerasuk Kawamatawong et al., 2022).

1.4.2. Forced Vital Capacity (FVC)

Base on Pediatric Respiratory Medicine (Peter D. Sly et al., 2008), the forced expiratory volume (FEV) measures how much air a person can exhale during a forced breath. When the patient cannot inhale deeply or exhale completely, the FVC will decrease. The average FVC for a elderly male is approximately four litres (one gallon). This parameter is intended to detect restriction.

1.4.3. Forced Expiratory Volume (FEV1)

Based on Pediatric Respiratory Medicine (Peter D. Sly et al., 2008), the forced vital capacity (FVC) is the total amount of air exhaled during the FEV test. It is used to determine the severity of an obstruction, with average FEV1 results ranging between two and four litres. A lower FEV1 value correlates to increased obstruction.

1.4.4. Peak Expiratory Flow Rate (PEFR)

Based on Pediatric Respiratory Medicine (Peter D. Sly et al., 2008), peak expiratory flow rate (PEFR) is the volume of air forcefully expelled from the lungs in one quick exhalation and is a reliable indicator of ventilation adequacy as well as airflow obstruction.

1.4.5. FEV1/FVC ratio

Typically, the FEV1/FVC ratio is given as a percentage (such as 75 percent). In a normal spirometry test, over three-quarters of lung volume can be expelled during the first second. Thus, the typical ratio ranges between 65 and 85 percent. The normal range of FEV1/FVC ratio is determined by the age of the patient.

1.5. Research Process

1. Literature review and research related to Spirometer, focusing on Portable type
2. Specify data collection and conduct survey
3. Analyse collected data and summarise development plan for portable Spirometer

1.6. Benefits or Expected Outcomes

1. Identify the required functionalities for Portable Spirometer that would be accepted.
2. Demonstrate possibilities to commercialise Portable Spirometer in Thai market

2. Fundamental Knowledge and Literature Review

In this section, the fundamentals of asthma are discussed, including its symptoms and triggering factors. This section examines asthma management in order to assist the patient in compliance with the doctor's orders. Throughout this section, the evolution and procedure of the spirometer and peak flow meter have also been demonstrated.

2.1. Asthma

Asthma is a non-communicable disease (NCD), typically found in children and adults (WHO, 2022). It is a long-term condition that is incurable but can be controlled by using medication and avoiding the triggers. Symptoms include coughing, wheezing, gasping for air, too much mucus, shortness of breath, and a tight feeling in the chest.

In the middle-income and low-income countries, asthma is often under-diagnosed and under-treated. It affects people's daily lives as it causes sleep disturbances, tiredness during the day, and poor concentration. In severe cases, asthma patients may need emergency treatment. Asthma is a life-threatening condition and may cause death.

Two main factors that cause asthma are genetic and environmental factors; details of these two are as follows:

1. Genetic Factors: The risk of asthma is increased if a close relative has asthma.
2. Environmental Factors:
 - Allergens such as pollen, grass pollen, dust, animal hair, and pollutants
 - Respiratory infection
 - Cold weather
 - Obese or Overweight

- Occupation conditions as exposure to irritants such as wood, dust, or chemicals

Asthma patients can be diagnosed with pulmonary function tests (PFTs) Figure 1 Pulmonary Function Test (American Lung Association) because this is the only non-invasive diagnostic that measures pulmonary function. The tests examine lung capacity, volume, flow rates, and gas exchange.

Spirometry is a particular form of lung function test. Spirometry assesses the lung volume (or how much air a patient can move in and out of their lungs) and lung flow (how rapidly air can move into and out of the lungs). It can also be used to evaluate lung health in smokers and individuals exposed to occupational and environmental hazards (Rob Pierce, 2005). Spirometry will inform the doctor as to whether the patient has an obstruction, limitation, mixed defect, or normal lung flow. A spirometry test will generate a series of data or parameters that will facilitate this assessment for clinical staff. The FEV1, FVC, and FEV1/FVC ratio parameters are the three most important spirometry parameters.



Figure 1 Pulmonary Function Test (American Lung Association)

Asthma can be diagnosed and managed using spirometry indicators such as the PEF and FEV1. FEV1 is regarded more sensitive than PEF for the detection of bronchoconstriction. Reduced FEV1/FVC ratio suggests airflow restriction. In children, the FEV1/FVC ratio is often larger than 0.90. Any values below this indicate airflow restriction (Alwin F. J. Brouwer & Brand, 2008).

By documenting bronchodilator response, increased diurnal changes, and a decrease following exercise or methacholine inhalation, FEV1 and PEF can be utilised to diagnose asthma. After receiving bronchodilators, a rise in FEV1 and PEF of greater than 12 and 20 percent, respectively, demonstrates reversibility of the airways and suggests a clinical phenotype of asthma.

PEFR is an effort-dependent measurement that necessitates family and child education to achieve the greatest benefit. PEFr has not been found to be an effective instrument for children with developmental problems and those under the age of five (Callahan et al., 2010). Despite the fact that PEFr monitoring is a cost-effective method for monitoring asthma medication, it cannot be the sole major tool for assessing asthma control (Wensley & Silverman, 2004). There was no significant link between clinical evaluation scores and FEV1/PEFR in a study of 75 children aged 5 to 14 with chronic asthma who were monitored for three months. However, the spirometric measurement PEFr was highly linked with FEV1. Consequently, despite the fact that FEV1 is superior to PEFr, it can be utilised at home when spirometry is not commonly available (Fonseca et al., 2006).

Asthma cannot be prevented, but its symptoms can be managed with regular monitoring and avoidance of asthma triggers. Patients and their family can therefore enjoy a regular life. However, 35% of Thai asthma patients had visited the emergency room and 44% had been absent from school or workplace according to asthma exacerbation (Theerasuk Kawamatawong et al., 2022). In addition, a cost per year the asthma patients spent is approximately 1,032 USD or 36,006 Baht (1 USD = 34.89 THB exchange rate as of 13 May 2022) (Bank of Thailand, 2022).

Following Global Initiative for Asthma (GINA) guidelines, asthma patients especially moderate to severe asthma, are recommended to do an asthma action plan and use a peak flow meter for self-monitor at home (GINA, 2022). Asthma action plan will help patients know which action are needed to be done once the symptoms is exacerbated and get worse. Asthma education and Asthma action plan would reduce the rate of hospitalisation and admitting the intensive care unit (ICU) (Tatiana Espinoza-Palma et al., 2009).

Advantages of the Asthma Action Plan (Kingthong Lakupoch et al., 2018)

1. Remind to take medication.

2. Indicate airway obstruction before chest discomfort or breathlessness occurs.
3. Patients can assess their condition during treatment and be able to choose the appropriate medication.
4. Patients are aware of their symptoms and appropriate activities.

2.2. Spirometer

A Spirometer is a device that measure lung capacity by estimating the volume of inhaled or exhaled air. The data is plotted into Spirogram to demonstrate the relationship between volume and time (Feher, 2017).

There were many attempts and invention to measure pulmonary volume. Dated back to A.D. 129 – 200, Claudius Galen, a Greek physician attempted to measure lung volume by having a child breathe into the bladder (Valentinuzzi, 2013). Unfortunately, its result was inconclusive. The true beginning of pulmonary function test (PFT) was conducted in 1846 when John Hutchinson, an English physician, invented the Spirometer (Figure 2). He turned a common gasometer into a precise instrument to measure exhalation volume and collected data from 2,130 individuals. The evidence showed a correlation between height, age, weight, and the volume of the vital capacity.

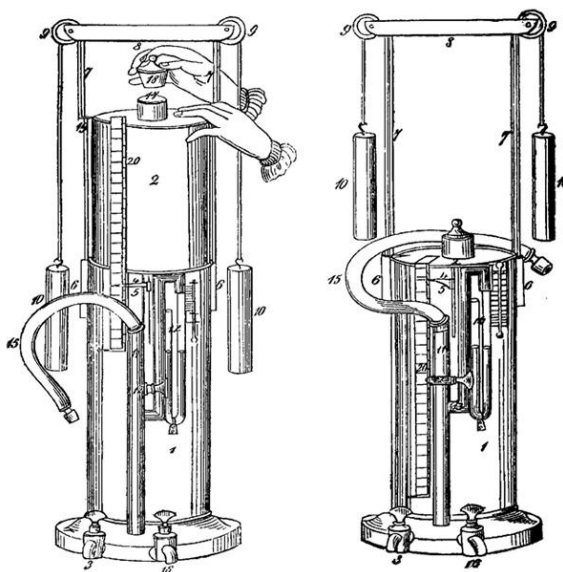


Figure 2 John Hutchinson's Spirometer (Hutchinson, 1846)

With more advanced knowledge and technologies, Hutchinson's invention has been modified and developed into various types of Spirometers; whole-body plethysmograph, pneumotachometer, fully electronic spirometer, peak flow meter, incentive spirometer, windmill-type spirometer.

Even though spirometers were initially developed for medical purposes, they can also be used to prevent or detect lung impairment in smokers and those who are exposed to environmental hazards. The non-smokers had higher flow rates than smokers in all other instances. The smokers were found to have restrictive, obstructive, and combination restrictive and obstructive impairments (B. P. Chattopadhyay et al., 2007).

2.3. Peak flow meter

A peak flow meter (Figure 3) is a portable, hand-held device that is used to measure the ability to push air out of the lung at maximum speed, Peak Expiratory Flow Rate (PEFR). A standard peak flow rate is based on a person's age, height, sex, and race. It is classified into three zones: green, yellow, and red.

- Green (Stable) indicates that the peak flow rate is between 80 - 100 percent of personal best.
- Yellow (Caution) indicates that the peak flow rate is between 50 – 80 percent of personal best. Patients' conditions might worsen and require to a change in medical treatment.
- Red (Danger) indicates that the peak flow rate is below 50 percent of personal best and immediately requires medical attention.

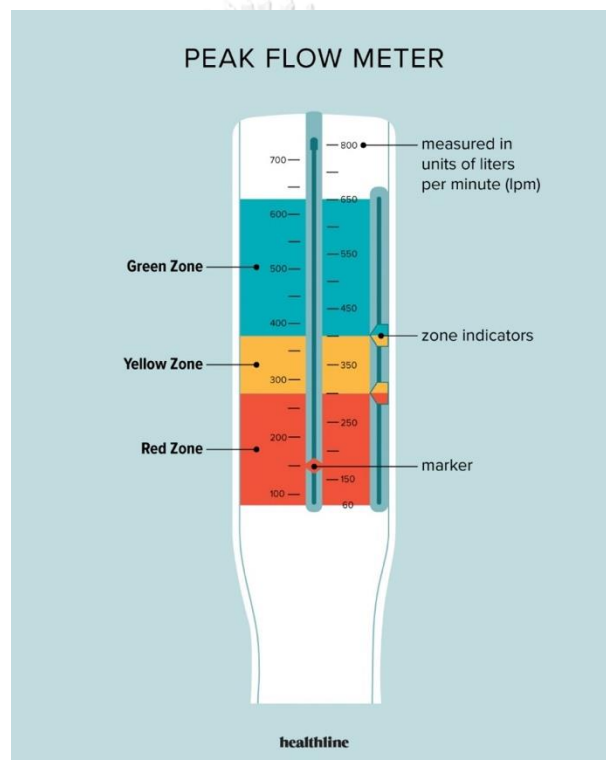


Figure 3 Peak Flow Meter (Whelan, 2021)

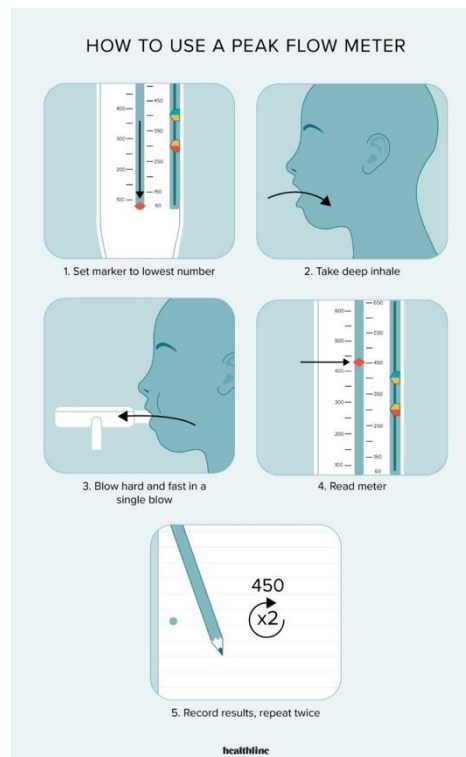


Figure 4 How to use Peak Flow Meter (Whelan, 2021)

A Peak flow meter is recommended to use in a newly diagnosed patients of asthma as per the steps illustrated in Figure 4. Patients aged five years old and older can use a peak flow meter on daily basis to monitor their asthma condition (Kingthong Lakupoch et al., 2018). Consistently using a peak flow meter could assess the asthma severity, provide treatment information to a doctor, and help identify the signal before asthma exacerbations.

2.4. Monitoring device currently available in the market

Asthma is a chronic disease that affects people all over the world. There are systems and devices built intended to help patients monitor their conditions and give instruction.

Table 1 Comparison of the peak flow meter available in the market




Brand	Value Measure	Price	Platform	Connection	Measuring Range (l/min)	Weight	Value Stored (readings)	Automatically	log reading	Removable Mouthpiece	Whole body Washable	Reminder	Warranty
 Omron PF9940 PeakAir Peak Flow Meter (Omron)	PEFR	\$25.75	Manual	No	50 – 750	454 g	N/A	✗	✗	✓	✓	✗	1 Year
 Philips Respironics Hs755 Personal Best Peak Full Range Flow Meter (Philips)	PEFR	\$21.00	Manual	No	Full 60 – 810, Low 50 – 390	85 g	N/A	✗	✗	✗	✓	✗	1 Year
 Mini-Wright Standard Range Peak Flow Meter (NationalAllergy)	PEFR	\$34.99	Manual	No	60 – 880	82.2 g	N/A	✗	✗	✓	✓	✗	1 Year

Table 1 Comparison of the peak flow meter available in the market










Brand	Value Measure	Price	Platform	Connection	Measuring Range (l/min)	Weight	Value Stored (readings)	Automatically log reading	Removable Mouthpiece	Whole body Washable	Reminder	Warranty
 Mini-Wright AFS Low Range Peak Flow Meter (NationalAllergy)	PEFR	\$29.99	Manual	No	30 – 400	62.37 g	N/A	✗	✓	✓	✗	1 Year
 eMini-Wright Digital Peak Flow Meter USB Download Version	PEFR	\$33.00 – 41.50	PC	USB	60 – 800	43 g	240	✓	✓	✗	✗	Warranty, but not specified
 MicroLife PF100 Digital Peak Flow and FEV1 Meter (MicroLife)	PEFR FEV1	\$75.77	PC	USB	50 – 900	430 g	240	✓	✓	✗	✗	2 years
 Quest AsthmaMD Lung Performance Peak Flow Meter (AsthmaMD Inc.)	PEFR	\$31.00	Manual	N/A	60 – 800	68 g	N/A	✗	✗	✓	✓	N/A

Table 1 Comparison of the peak flow meter available in the market

Brand	Value Measure	Price	Platform	Connection	Measuring Range (l/min)	Weight	Value Stored (readings)	Automatically log reading	Removable Mouthpiece	Whole body Washable	Reminder	Warranty
 Smart Peak Flow – Headphone jack version (SmartAsthma)	PEFR	€44.99	Mobile Phone	Headphone Jack	60 – 800	19 g	N/A	✓	✓	✗	✓	2 Years
 Smart Peak Flow Wireless (SmartAsthma)	PEFR	€57.99	Mobile Phone	Bluetooth	60 – 800	19 g	N/A	✓	✓	✗	✓	2 Years
 CONTECMED SP10 Spirometer	PEFR FEC FEV1	\$199	PC	Bluetooth		150 g	Yes	✓	✓	✗	✗	6 Months
 CONTEC SP70B (CONTEC)	PEFR FEC FEV1	\$94.99	Mobile Phone	Bluetooth		130 g	9,999	✓	✓	✗	✗	6 Months
 EasyOne® Air (NDD Medical Technologies)	PEFR FEC FEV1	\$2,299	Mobile Phone / PC	Bluetooth		356 g	10,000	✓	✓	✗	✗	N/A

From Table 1, most of the peak flow meter available in the market are manual device. Most of the digital version requires a wire to connect to PC and are not appropriate to carry around. Portable spirometer from SmartAsthma seems to be the most completed in term of functionality and usability.

SmartAsthma (SmartAsthma) is a peak flow meter developed under the cooperation of Imperial College, London, Harvard Medical School, and SANDOZ: a Novartis company. The concept started in 2014 and commercialised in 2021. The headphone jack version (Figure 5) is sold at €44.99 and the Bluetooth version (Figure 6) at €57.99, excluding delivery fee. Consequently, it is not affordable for Thai people to buy and use it to monitor asthma.



Figure 5 Headphone jack version

(SmartAsthma)



Figure 6 Bluetooth version

(SmartAsthma)

In Thailand, there was an attempt to develop a portable Spirometer in 2011 by Associated Prof. Dr. Pattarasinee Bhattarakosol and a group of Bachelor students (Nuntawat Sawasratanathon et al., 2011). The application was developed to work as a peak flow meter on Nokia Smartphones. It was applied for a copyright in 2018 and cooperating with a private company to launch an application on Play Store, Lung Care. However, the application is platform-dependent and required to pass medical standards before being published. The application was withdrawn from the Play Store.

3. Research Methodology

Section 3 displays the research technique, including sample size and questionnaire creation procedure. In section 3.3, the objective of each question has been specified.

3.1. Population and Sample

Using the sample size formula

$$n = \frac{Z_{\frac{\alpha}{2}}^2 \times P(1 - P)}{e^2}$$

$Z_{\frac{\alpha}{2}}$ is confident level at 95% = 1.96

e is Margin of error = 0.1

P is Probability that people will be interested in the portable spirometer = 75%

A questionnaire targeted a minimum of 72 respondents.

3.2. Validity of research instrument

To examine the questionnaire's validity, it has been sent to the following individuals for evaluation and scoring:

1. Associate Professor Dr. Nithinant Thammakoranonta, National Institute of Development Administration
2. Associate Professor Dr. Patrawadee Makmee, College of Research Methodology and Cognitive Science
3. Dr. Tanadol Rojanasartikul, Head of EMS, Chulalongkorn University

Step one: The adviser has examined the questionnaire.

Step two: The questionnaire was modified in response to the advisor's feedback and recommendations.

Step three: After the modification, the Index of Item-Objective Congruence (IOC) was applied to determine the content validity. Two specialists in the field of training and development and one expert in the medical profession reviewed the questionnaire (see in Appendix B).

The Item-Objective Congruence (IOC) was used to evaluate the questionnaire items based on the score range from -1 to +1.

- Congruent = + 1
- Questionable = 0
- Incongruent = -1

The items with scores lower than 0.5 were revised. On the other hand, the items with scores higher than or equal to 0.5 were reserved.

Part 1 : There are 7 questions and all of them have score more than 0.5

Part 2 : There are 4 questions and all of them have score more than 0.5

Part 3 : There are 4 questions and all of them have score more than 0.5

Part 4 : There are 3 questions and all of them have score more than 0.5

3.3. Questionnaire

To reach a large number of respondents in a short period of time and adhere to the social distancing policy, a Google Form survey was created and distributed on social media platforms such as LINE, Facebook, etc. The complete questionnaire is available in Appendix A.

The questionnaire contains four parts:

Part 1 General information

Respondents were requested to provide demographic information such as age, gender, degree of education, etc. The data can be analysed for purchasing power and the potential user of the portable spirometer can be identified.

Part 2 Purpose of spirometer usage

This part aims to divide respondents between those who are familiar with/have used the devices and those who are not. This part is then utilised to survey product demand and usage motivation.

Part 3 Factors affecting spirometer selection

To summarise the characteristics and functioning of the portable spirometer, the respondents are provided with the device's physical characteristics and then asked to select their preferred mobile connection and material. The functions and sanitisation methods are ranked from least important/preferred to most important/preferred.

Part 4 Price expectation

For the purpose of establishing the pricing structure, respondents are required to select the purchase plan and price range according to their plan.

4. Result

In this section, the demographics of the respondents have been reported. The data analysis would aid in the identification of prospective clients, necessary characteristics, and an acceptable pricing.

4.1. General information of the respondents

The total number of the respondents participated in the survey is 256 persons. The questionnaire contains demographic related to age, gender, education level, occupation, salary, and residence. The awareness of Spirometer/Peak Flow Meter and the experience of using it have also been included for analysis. The following insights are extracted from Table 2 and analysed as per followed:

- Majority of respondents are in the age of 26 – 35 (43.75%) and 36 – 46 (32.05%) years old.
- Most of the respondents (33.20%) are employee with salary at 100,000 baht per month and above.
- 15.63% of the respondents have congenital disease and 87% of them had ever used Spirometer/Peak Flow Meter.

Table 2 General Information of respondents

Data	Respondents	Percentage
Age		
20 - 25	6	2.34%
26 - 35	112	43.75%
36 - 45	82	32.03%
46 - 55	39	15.23%
56 - 70	14	5.47%
70+	3	1.17%
Gender		
Male	99	38.67 %
Female	149	58.20 %
LGBTQ+	8	3.13 %
Education Level		
Under High School/Vocational Certificate	1	0.39%
High School/Vocational Certificate	0	0 %
High Vocational Certificate	0	0 %
Bachelor's	85	33.20%
Master's	158	61.72%
Doctor's	12	4.69 %
Occupation		
Student	7	2.73%
Employee	175	68.36%
Civil	24	9.38%
Servant/State		

Table 2 General Information of respondents

Data	Respondents	Percentage
Enterprise		
Employee		
Business Owner	22	8.59%
Freelance	8	3.13%
Housewife	9	3.52%
Other	11	4.30%
Salary		
< 15,000 THB	6	2.34%
15,000 - 34,999 THB	26	10.16%
35,000 - 69,999 THB	67	26.17%
70,000 - 99,999 THB	50	19.53%
> 100,000 THB	107	41.80%
Residence		
Bangkok Metropolis and Vicinity	242	94.53%
Upcountry – district area	6	2.34%
Upcountry – not district area	8	3.13%
Congenital disease		
Yes	40	15.63 %
No	216	84.38 %
Know spirometer/peak flow meter		
Yes	56	21.88 %

Data	Respondents	Percentage
No	200	78.13 %
Had ever used spirometer/peak flow meter		
Yes	32	12.50 %
No	224	87.50 %

4.2. Evaluation Finding

From Figure 7 most of respondents require spirometer/peak flow meter for family and themselves, 64.45% and 25.00% respectively. There are 1.56% who were not sure whether they required the devices at the moment and 3.91% of the respondents stated that they do not require the device, but with the meaningful reasons, e.g. COVID-19 infection, they may change the decision.

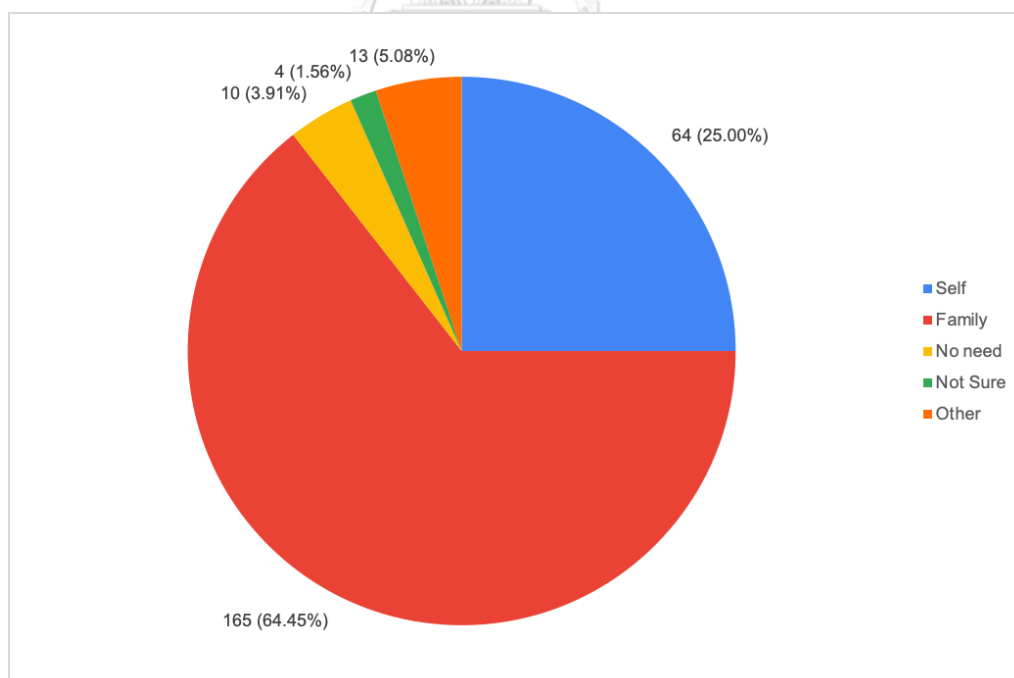


Figure 7 The targeted group that the respondents would buy the device for

In Figure 8 and Figure 9 among the respondents who indicated they would purchase a portable spirometer for themselves, their family, or a friend, the man with a salary of more than 100,000 Baht is the most prepared to spend, followed by the woman with a salary in the same range.

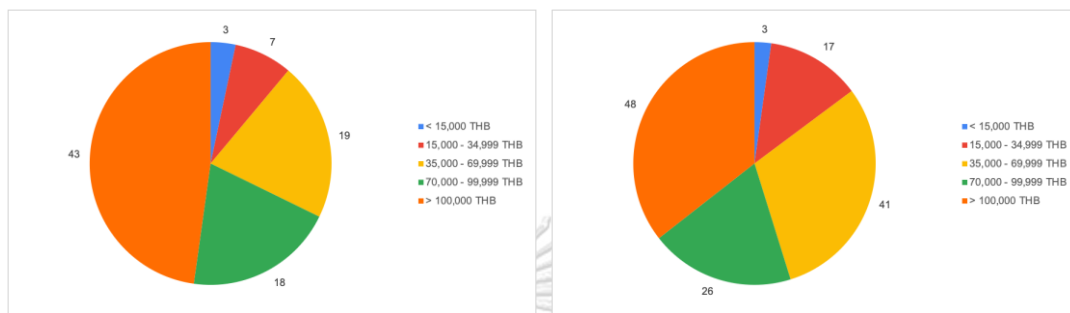


Figure 8 Male respondents

Figure 9 Female respondents

Respondents can choose more than one reasons of using the spirometer/peak flow meter. In Figure 10 among 386 responses, monitoring lung health is the most chosen reason of the respondents. Following are watching out for COVID-19 and following up on lung health after being infected by COVID-19 respectively.

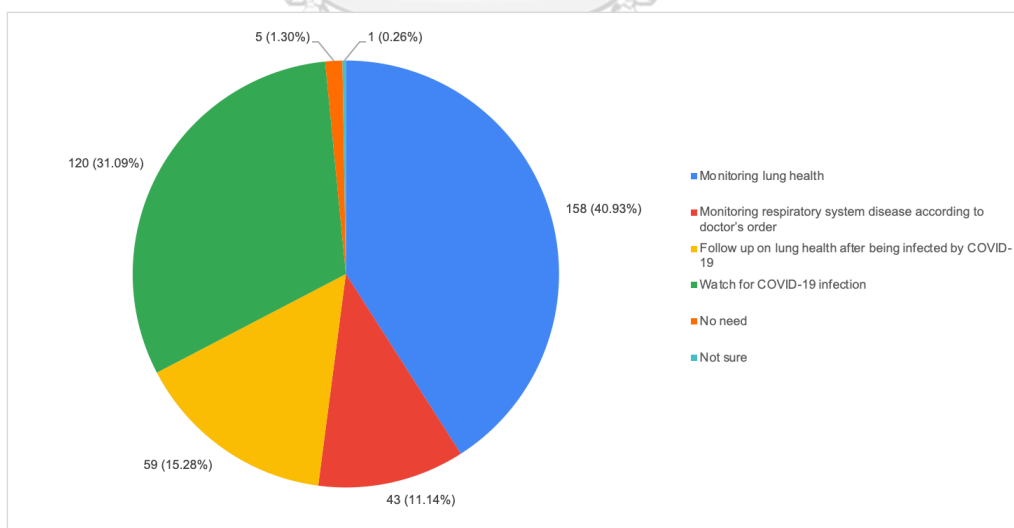


Figure 10 The reasons of using spirometer/peak flow meter

For the most preferred connection method between mobile phone and the portable is Bluetooth with 93.75% of responds as illustrated in Figure 11

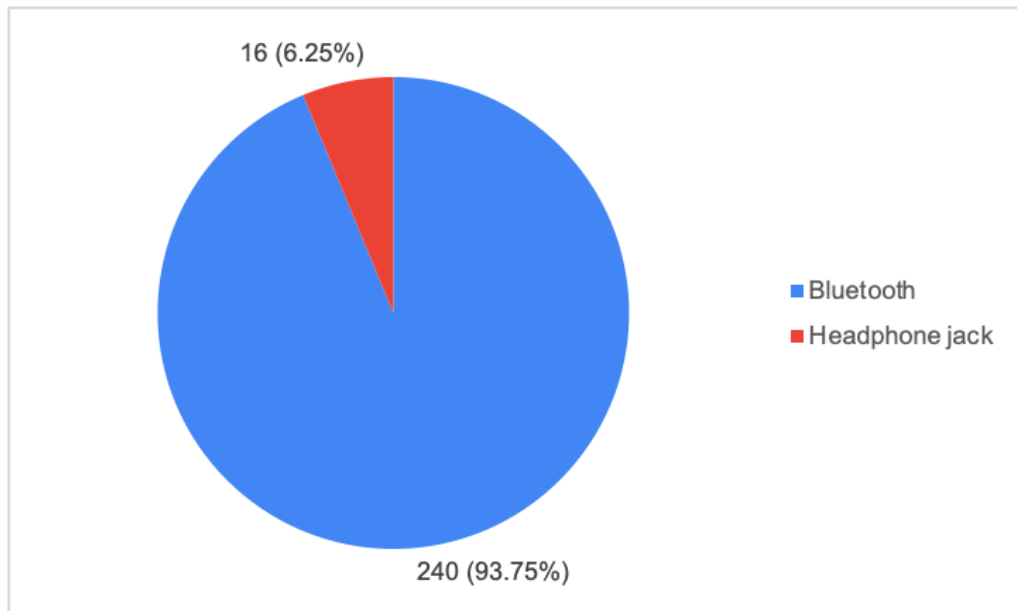


Figure 11 Preferred mobile connection

Figure 12 shows that 80.86% of respondents prefer to use a device made of plastic. There are also other suggested materials that should be taken into consideration such as recycle material and environmentally friendly material. Some respondents had no preferred material but had a concern on hygiene instead.

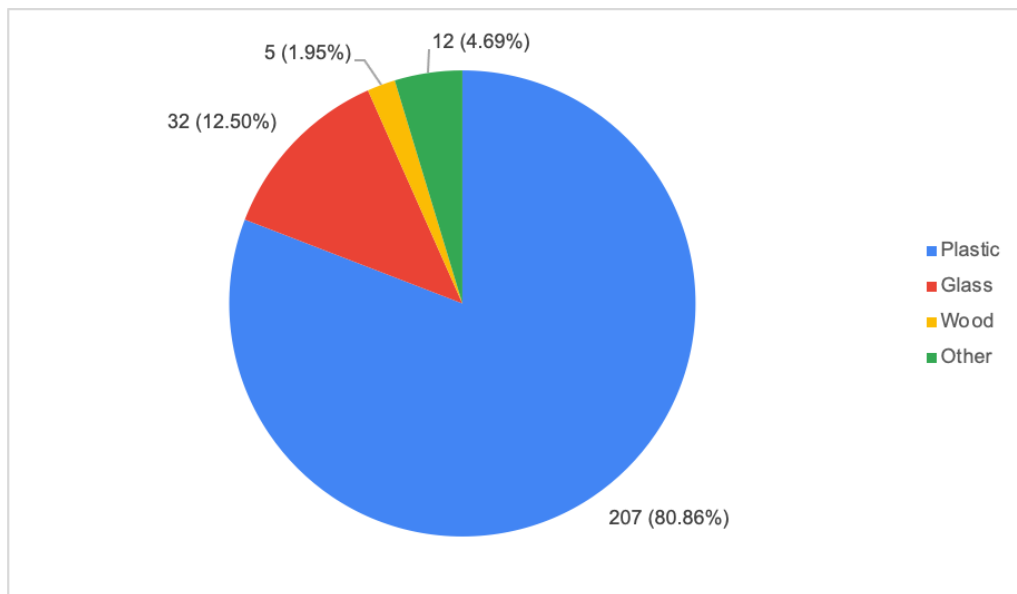


Figure 12 Preferred material

Respondents were asked to rate the significance of the required functions for the development of a portable spirometer on a scale from 1 to 5. The total score for each function is 5, and the resulting score is displayed as an average. As seen from Figure 13, the function can be ranked as followed:

1. Easy to clean
2. Parts of a device can be changed/replaced for hygiene
3. Device is durable
4. Easy to carry
5. Data is automatically synced and stored in the connected mobile phone
6. Lightweight
7. Remind user to use Spirometer to log data

Respondents have selected ease of cleaning as the most significant feature. Components of a device that can be changed/replaced for hygiene are the second most important function, while durability is the third most critical. Furthermore, there is no difference in function ranking between individuals familiar with and unfamiliar with spirometer/peak flow meter.

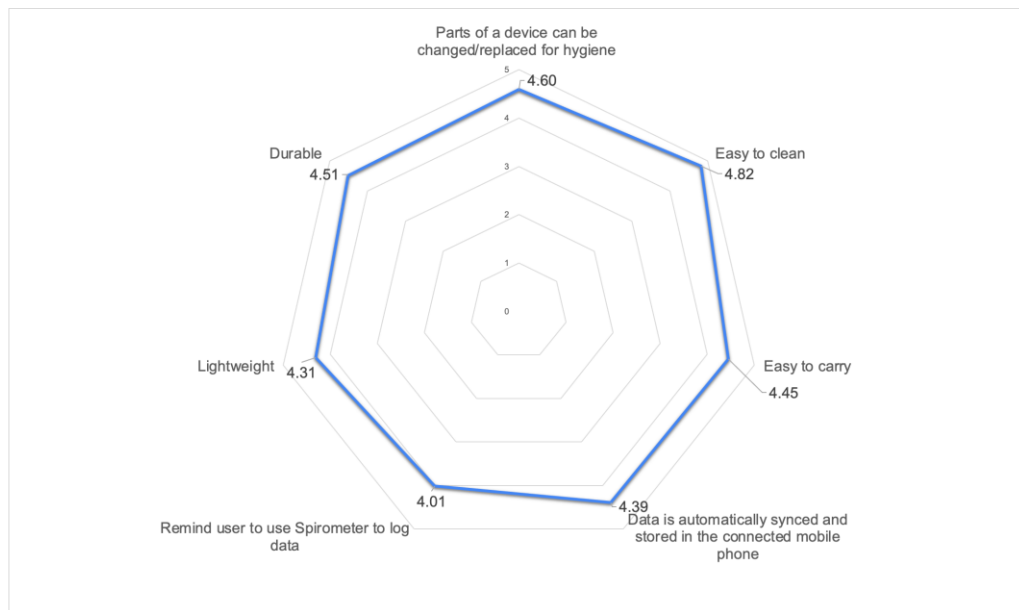


Figure 13 Function Scoring

The respondents were asked to assess the sanitation technique. The score ranges from 1 to 5, where 1 indicates that respondents strongly oppose using the provided approach and 5 indicates that respondents strongly support using the specified method. Each method is worth a total of 5 points. As indicated in the preceding section, respondents were extremely concerned with hygiene. The components of the device must be detachable. According to Figure 14, respondents supported washing and reusing parts rather than replacing them since individual pieces are less expensive than the entire gadget. Those who know spirometer/peak flow meter and those who do not have no advantage when selecting a method of sanitation.

It is also acceptable to clean with alcohol spray. To employ this procedure, food-grade alcohol is required.

There are also intriguing suggestions regarding sanitation techniques. Some respondents suggested using ultraviolet light or steam to clean the components, similar to how the parents clean the infant bottles. UV sterilisation is also an acceptable strategy for reducing mask shortage during the COVID-19 pandemic by sterilising face masks (Eun-Suk Jang & Chun-Won Kang, 2020). Due to the added

cost of the UV sterilisation machine, however, this method is only suitable for a group of users who already possess one.

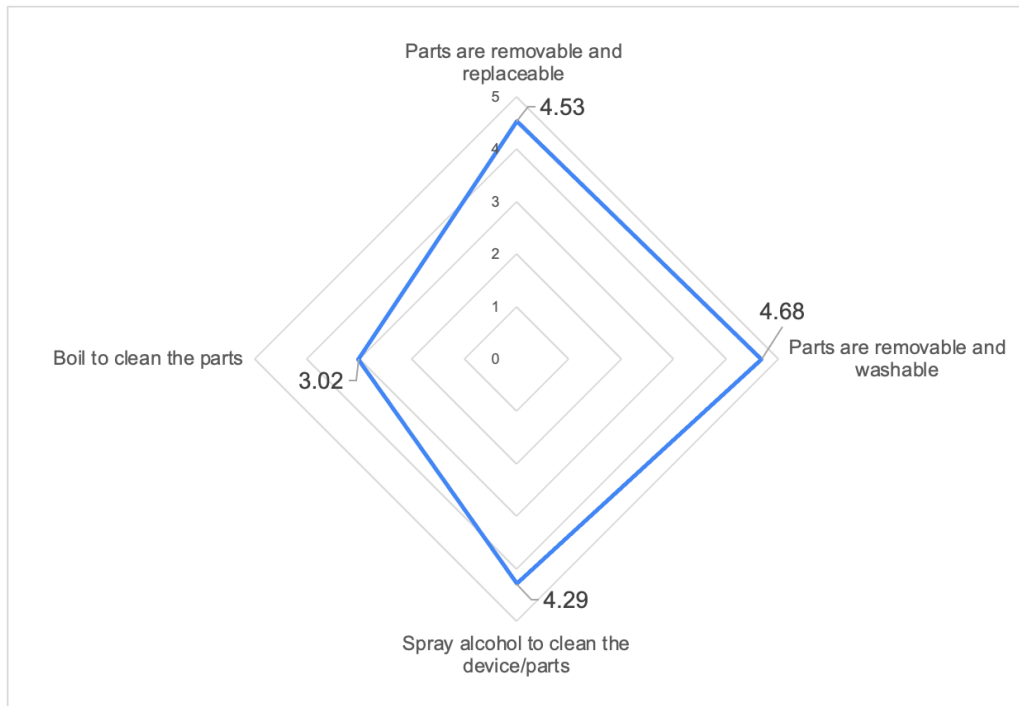


Figure 14 Sanitisation method

The majority of respondents (Figure 15) preferred a one-time purchase or state welfare for the payment plan. The subscription model is the least desirable option.

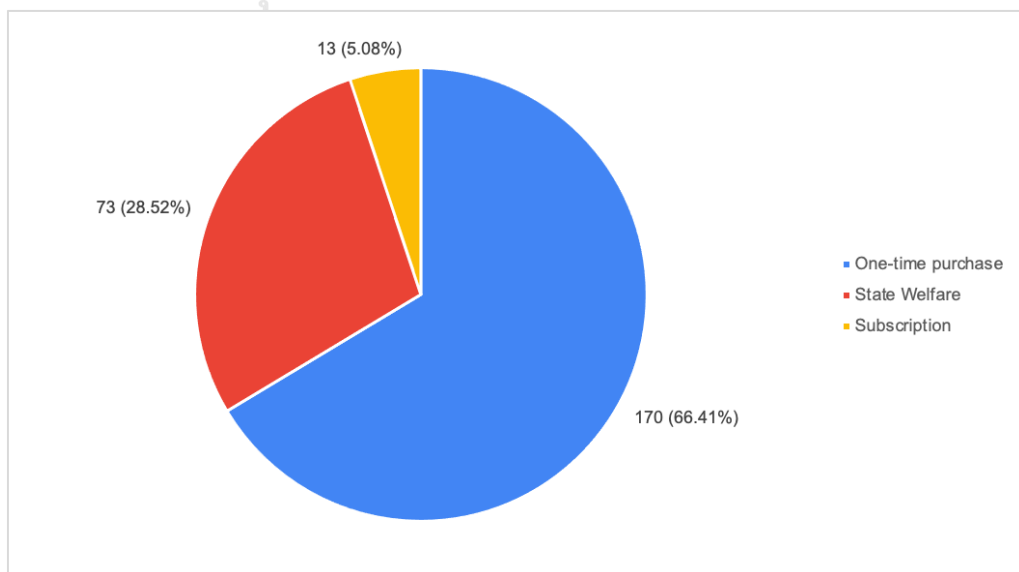


Figure 15 Preferred Purchasing Plan

Focusing on the one-time purchase model (Figure 16), 41.21 percent of respondents are willing to pay between 501 and 1,000 Baht for a device and service, followed by 31.52 percent who are willing to pay between 251 and 500 Baht. 12.73 percent of respondents are surprisingly willing to pay more than 1,000 Baht. 12.73 percent of respondents are surprisingly willing to pay more than 1,000 Baht.

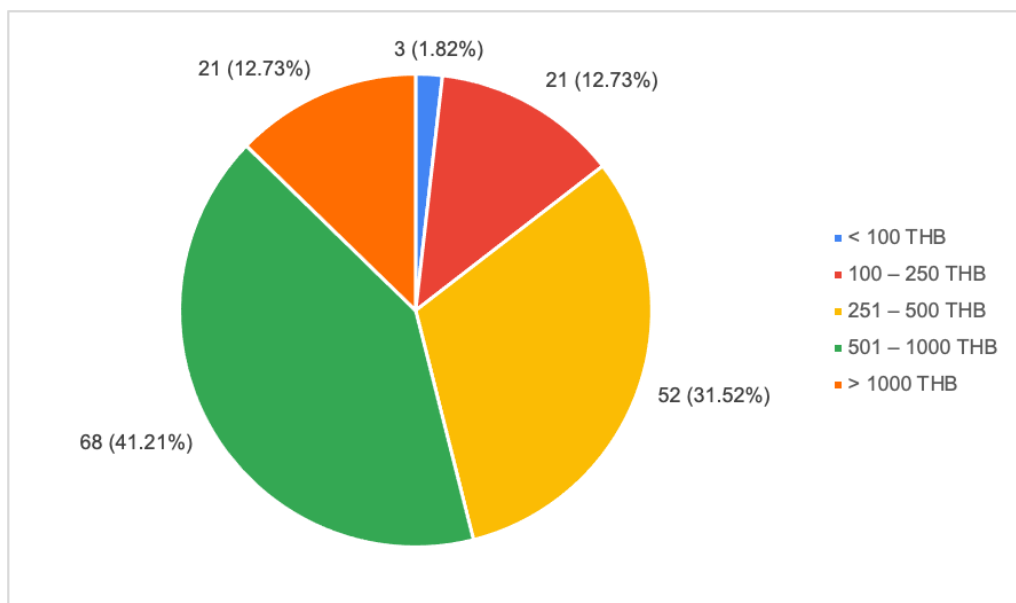


Figure 16 Acceptable price for one-time purchase

4.3. Development Roadmap

To develop a prototype of a portable Spirometer, it can be divided into two parts: device and application. The device development will be based on the survey result while the application will be based on the research of Associated Prof. Dr. Pattarasinee Bhattarakosol and Bachelor students (Nuntawat Sawasratanathon et al., 2011).

4.3.1. Device

According to the results of the survey, gadget hygiene is a top priority for respondents. To clean the equipment, respondents favoured washing or

replacing the components. Additionally, the equipment must be portable and durable. The most common form of payment is a one-time purchase.

The function to construct a prototype of the portable Spirometer may be summarised as follows, based on the survey results and the functionality of the existing product:

- The device should be made of plastic.
- The device should be easily detachable for cleaning or replacement purposes.
- The device should connect to the mobile phone through Bluetooth.
- The data should sync and store automatically on the mobile phone.

4.3.2. Application

The application is designed to be web-responsive, platform-independent, and compatible with mobile phones, laptops, and desktop computers. A responsive web application also avoids the cost of publishing the application to the AppStore or Google Play.

Similar to other peak flow meters on the market, PEFR is a standard measurement that should be displayed in the application with a clear instruction according to the lung health. FEC and FEV1 should also be included in order to estimate lung health accurately.

The application will receive the sound wave from the device's microphone and deliver it through Bluetooth to the application. The sound wave will be converted into a lung volume, which will then be compared to the average lung volume. The normal lung capacity varies by gender and race (Lundy Braun et al., 2013). PEFR, FEC, and FEV1 values will be recorded within the application. Instructions are provided based on the diagnosis and asthma action plan.

4.3.3. Prototype Testing

Due to the fact that Thai people are unfamiliar with the spirometer/peak flow meter, a prototype will be constructed and tested with the intended user to collect input and determine the acceptance. The test will be administered to asthma patients, individuals with Long COVID, and typical users under medical supervision. Through a survey and in-depth interview, researchers will assess the acceptance and collect comments for future enhancements.

In order to protect the invention, the patent will be registered. Furthermore, this invention will be created as a prototype and be tested at Chulalongkorn Hospital's Division of Pulmonary Disease and Pulmonary Critical Care to confirm the design and also follows the testing result. Then, the research outcome will be published in an international publication to announce the Thai medical equipment. Thus, this new portable spirometer must be approved by medical professionals for its reliability and certified ISO13485. In order to sell in Thailand, it must also be approved by the Thai FDA.

5. Commercial Feasibility

The objective of this chapter is to determine the commercial feasibility of the portable spirometer. This includes the market analysis, customer analysis, competitor analysis, other external factors, and marketing plan.

5.1. Situation Analysis

5.1.1. Market Analysis

According to data from worldlifeexpectancy.com, 3.43% of Thai population died from asthma and occurs in male rather than female. Approximately there are 8 – 9 asthma patients died every day.

5.1.2. Customer Analysis

The targeted customers are those who have diagnosed asthma or those who have concerns on their lung health from COVID-19 pandemic.

5.1.3. Competitor Analysis

In Thailand, there are traditional spirometer (Figure 17) and digital peak flow meter (Figure 18) available in the market. The digital version can be found from online shopping platform such as Lazada, Shopee, etc. but they are imported and no authorised reseller in Thai.



Figure 17 Traditional Peak Flow Meter



Figure 18 CONTECMED SP10 Spirometer

5.2. PESTEL

5.2.1. Political Factor

The government has subsidised the cost of health care for government employees.

5.2.2. Economic Factor

According to Trade Policy and Strategy office (Trade Policy and Strategy Office, 2022), the inflation tends to increase in May 2022 as a result of high energy prices relative to the previous year. The primary contributors were the termination of the price ceiling in April, the end of the diesel excise tax cut in May, and a gradual increase in the price of cooking gas (LPG) from April to May 2022. Also, commodity prices tend to increase, particularly for fresh food and food items, as a result of high production and ingredient costs. In addition, the costs of energy and commodities on the global market, the sanctions of the United States and its allies, the COVID-19 issue, and climate change are future factors that will affect inflation and should be properly studied. The projected inflation rate for 2022 is between 4.0 and 5.0 percent (with a median of 4.5 percent), which is consistent with the current situation.

The Producer Price Index (PPI) increased 12.8% (YoY) in April 2022 due to manufacturing, raw material, and logistical expenses, as well as the depreciation of the Thai Baht. The primary contributions were of petroleum,

natural gas, and other related items. In addition, food and agricultural products affected the PPI due to their limited availability and rising demand.

The Construction Materials Price Index (CMI) grew 8.8 percent YoY due to price increases across all product categories. The primary contributors were high output and raw material (oil, steel, coal, and aluminium) prices that tracked the global market. The pricing was the result of a deficiency in supply resulting from lower production in producing nations.

The Consumer Confidence Index (CCI) rose from 43.8 to 45.7 over the previous month. The country's economy was boosted by a considerable increase in exports and the recovery of the tourism industry.

Table 3 Economic and Trade Indices

	Index	%MoM	%YoY	%AoA	%YoY March2022
Headline Inflation CPI	105.15	0.34	4.65	4.71	5.73
Core Inflation Core CPI	102.57	0.14	2.00	1.58	2.0
Producer Price Index (PPI)	114.0	1.8	12.8	10.6	11.4
Construction Materials Price Index (CMI)	122.2	2.1	8.8	7.6	8.6
Consumer Confidence Index (CCI)	45.7		43.8		
	Apr-22		Mar-22		

As seen in Table 3, the rising rate of inflation reflects a decline in the purchasing power of Thai citizens. In addition, the rising producer price index (PPI) indicates higher production costs, which may influence the manufacture of portable spirometers. Higher production costs may result in an increase in the product's selling price.

5.2.3. Social Factor

The Thai population has a limited understanding of respiratory system diseases. With the erroneous belief that respiratory system diseases are contagious, no assistance is offered to a patient experiencing an exacerbation. The portable spirometer could help patients monitor their symptoms and receive condition-specific instructions, resulting in a drop in hospitalisation and mortality rates.

5.2.4. Technological Factor

Figure 19 shows that 86.4 percent of Thais own a smartphone (National Statistical Office of Thailand, 2020). Moreover, the government has already launched the smartphone-required Thai Chana initiative, thus the Thai population should already possess smartphones. To construct a portable Spirometer and attach it to a smartphone, technical accessibility would be high.

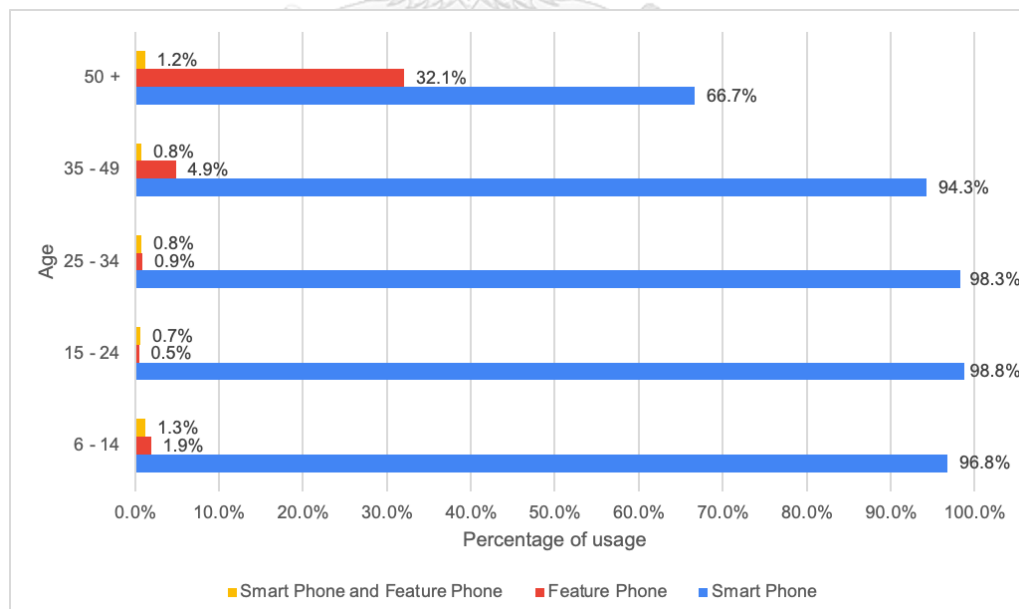


Figure 19 Type of Mobile phone usage categorised by age

5.2.5. Environmental Factor

In addition to allergens (dust, hay, etc.), changes in weather can also provoke asthma exacerbations in asthmatic patients. In addition to asthma patients, COVID-19 and PM2.5 pose a concern. As they all have direct effects on the lungs, there is an opportunity to introduce and market the portable spirometer.

5.2.6. Legal Factor

To produce the portable spirometer, the devices must be ISO 13485 certified for medical devices and Thai FDA approved (Medical Devices Intelligence Unit, 2014). Doctors must validate the application's trustworthiness and reliability.

5.3. Industrial Analysis

5.3.1. Industry Rivalry

Industry Rivalry is LOW. The majority of Spirometers on the market are analogue and unsuitable for portability. The digital portable spirometer available on online shopping platform are imported device and expensive. In addition, there is no authorised reseller in Thailand. Once a device malfunctions, it is difficult for the user to repair it. The majority of Peak Flow Meters available on the market are analogue and can only measure PEFr.

5.3.2. Bargaining Power of Suppliers

Suppliers are separating into two parts, device manufacture and software development.

For device manufacturing, the **bargaining power of suppliers is HIGH.** According to the survey, respondents prefer plastic devices. Given that it is a medical equipment, the plastic must be of medical grade. The device is also

newly designed, necessitating a specific volume of manufacture in order to bargain for a new mould.

In software development, the **bargaining power of suppliers is LOW**. The functions of the portable spirometer are uncomplicated. There are software companies and independent developers on the market who are willing to take on the project.

5.3.3. Bargaining Power of Buyers

Bargaining power of buyers is LOW. In Thailand, there is no authorised dealer for digital portable spirometers. The affordable device has inferior function as it is analogue or is not portable. Therefore, the customers do not have many options.

5.3.4. Threats of New Entrants

Threats of new entrants is HIGH. Once a device is introduced, it is simple to copy it. The software must be certified, making it more difficult to copy. Therefore, they are able to use the counterfeit device with our authentic software.

5.3.5. Threats of Substitutes

Threats of substitutes is LOW. The market-available spirometer is not portable, and the peak flow meter is an analogue device.

5.4. SWOT Analysis

5.4.1. Strengths

1. Compared to the digital version of the portable spirometer accessible overseas, the newly created portable spirometer is less expensive.
2. Since the product is created and manufactured in Thailand, it is easier for clients to obtain support and a warranty.

3. The device can be used at home to pre-screen a person's lung health and provide instructions based on their condition.
4. The device is certified by Thai FDA.

5.4.2. Weaknesses

1. The portable Spirometer is made of plastic, a material that is not environmentally friendly.

5.4.3. Opportunities

1. The COVID-19 pandemic enhances Thais' awareness of the importance of self-monitoring their health. The device can be used at home to pre-screen a person's lung health and provide instructions based on their condition.
2. In the event of an accident resulting in a lung rip, the patient is unaware and lacks monitoring equipment.

5.4.4. Threats

1. When a product is introduced on the market, counterfeiting may occur.
2. The Thai population is unaware of health care and wait for the sickness to develop before taking a treatment. Even if the item is affordable, there is no desire in finding equipment.
3. Lack of personal responsibility resulting in a severe asthma attack

5.5. Marketing Plan

5.5.1. Segmentation

- Thai asthma patients who seek for convenience in monitoring their symptoms
- Thai people who concern on their lung health

5.5.2. Targeting

- Thai patients who have been diagnose of asthma at the age of 18 – 70 years old and can be able to use a smartphone
- Thai people who want to monitor their lung health as they are exposed to PM2.5 or had recovered from COVID-19
- Doctors and medical staff in Pulmonology department of Chulalongkorn Hospital

5.5.3. Positioning

A portable Spirometer is an equipment that monitors lung health and aims to lower the hospitalisation rate of asthma patients. It can also be used with individuals who are exposed to toxic compounds, pollution, and long COVID. The spirometer provides comprehensive lung information but is not portable. It is inconvenient for patients to undergo daily spirometry tests at the hospital to check their condition. Although the peak flow meter is a portable analogue device, it does not provide comprehensive lung information. Figure 20 demonstrates that the portable spirometer combines the benefits of the conventional spirometer and peak flow meter. The portable spirometer, which is portable and less expensive to acquire, nonetheless provides the doctor with comprehensive information for treatment analysis.

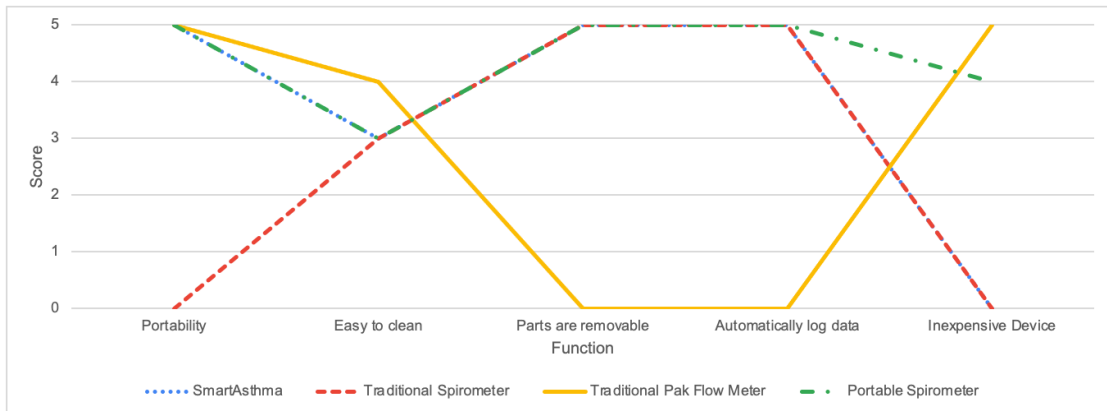


Figure 20 Function Comparison

Figure 21 depicts the placement of the portable spirometer relative to other portable devices on the market. The typical spirometer, which offers detailed lung information to medical personnel but is not portable, has been excluded from the illustration.

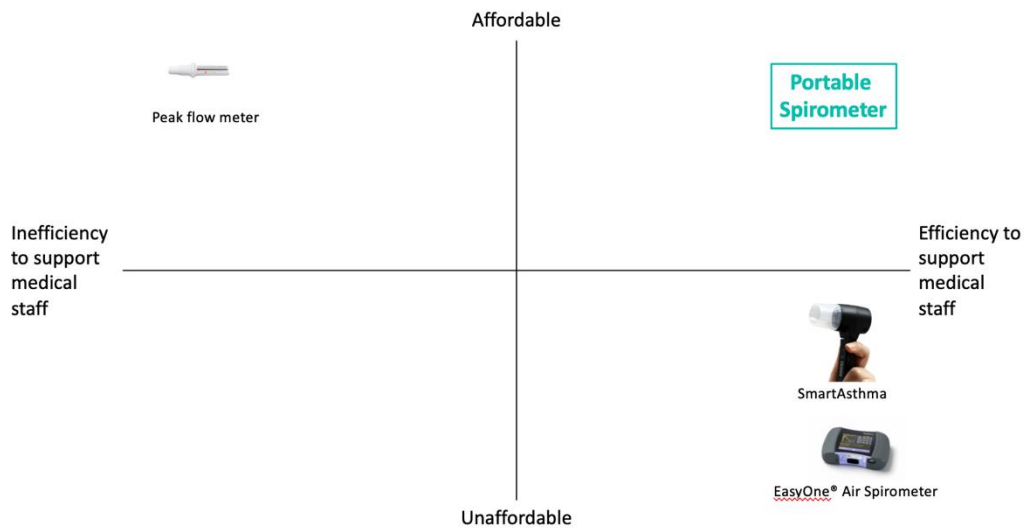


Figure 21 Positioning

5.5.4. Marketing Strategy

Product

The portable spirometer is offered as a convenience and accurate lung monitoring device at an affordable price for Thais. The product will be

tested with Thai asthma patients under medical professionals supervision. It is also planned to be certified ISO13485 and seek for Thai FDA approval.

Price

The unit cost is 455 Baht, which includes manufacturing, software development, IT infrastructure, sales, and marketing expenses. In order to cover these expenses in five years, at least 0.27 percent of asthma patients must be acquired.

According to the survey, 41.21 percent of respondents were willing to pay between 501 and 1,000 Thai Baht. Therefore, a selling price of 800 Thai Baht is acceptable and still provides a margin of 43.13 percent per unit.

Place

Primarily, the portable spirometer will be distributed via online platforms such as Facebook, LINE, and e-commerce platforms. In addition, a partnership will be established with a private hospital. Using the hospital's showcase exhibition, the portable spirometer will be introduced to Pulmonary Department patients.

Promotion

To maintain relationship with customers in long term, every purchase on Facebook and LINE will be entitled for points in loyalty program. The point can later be used as a discount. Membership is also divided into tiers; each tier will receive different level of benefits.

For online e-commerce platform, the brand will occasionally participated in the campaign which will increase customer awareness to brand and improve sales.

5.6. Financial Plan

Due to the fact that the portable spirometer has not yet passed prototype testing, the manufacturing cost may be affected by changes in the specifications. Software development and product manufacture will be conducted in Q1 – Q3 of year 1 while the public sales is targeted to start in Q4 of year 1. Cost benefit analysis and cumulative cash flow have been calculated based on the following financial assumptions:

Exchange rate	: 1 USD = 34.89 THB (exchange rate as of 13 May 2022)	
	(Bank of Thailand, 2022).	
Inflation rate	: 4.65%	
Producer Price Index	: 12.80%	
Thai Population	: 69.43 million	
Asthma Patient	: 7% of Thai population	= 4.86 million people
Targeted at	: 2.5% of Asthma patients	= 121,503 patients
Expected growth rate	: 10% per year	

5.6.1. Best Case

The sales start in Q4 of year 1 and expect for growth rate at 10% per year. The devices are sold at 950 Baht per piece.

Table 4 Cost Benefit Analysis (Best case)

	Y1	Y2	Y3	Y4	Y5
CAPEX	583,900.00	0.00	0.00	0.00	0.00
Application Development	583,900.00	0.00	0.00	0.00	0.00
OPEX	17,855,046.58	73,030,586.66	80,084,556.59	87,833,236.35	96,346,332.83
Sales, general and administration	2,505,000.00	2,951,130.00	3,088,357.55	3,231,966.17	3,382,252.60
Marketing	1,000,000.00	1,046,500.00	1,095,162.25	1,146,087.29	1,199,380.35
Device Production	13,820,909.38	68,596,065.72	75,456,031.56	83,001,686.04	91,302,316.56
O365	16,747.20	17,525.94	18,340.90	19,193.75	20,086.26
Certification	100,000.00	0.00	0.00	0.00	0.00
Cloud Storage	90,000.00	94,185.00	98,564.60	103,147.86	107,944.23
Office Rental	180,000.00	180,000.00	180,000.00	180,000.00	180,000.00
Electricity	18,000.00	18,000.00	18,000.00	18,000.00	18,000.00
Water	6,000.00	6,000.00	6,000.00	6,000.00	6,000.00
Maintenance	58,390.00	58,390.00	58,390.00	58,390.00	58,390.00
Other	60,000.00	62,790.00	65,709.74	68,765.24	71,962.82
Depreciation of CAPEX	128,780.00	128,780.00	128,780.00	128,780.00	128,780.00
Depre-Computer	12,000.00	12,000.00	12,000.00	12,000.00	12,000.00
Amor-Web Dev	116,780.00	116,780.00	116,780.00	116,780.00	116,780.00
Revenue	6,834,515.63	125,881,078.05	144,908,692.95	166,811,745.04	192,026,311.80
Devices	6,834,515.63	125,881,078.05	144,908,692.95	166,811,745.04	192,026,311.80

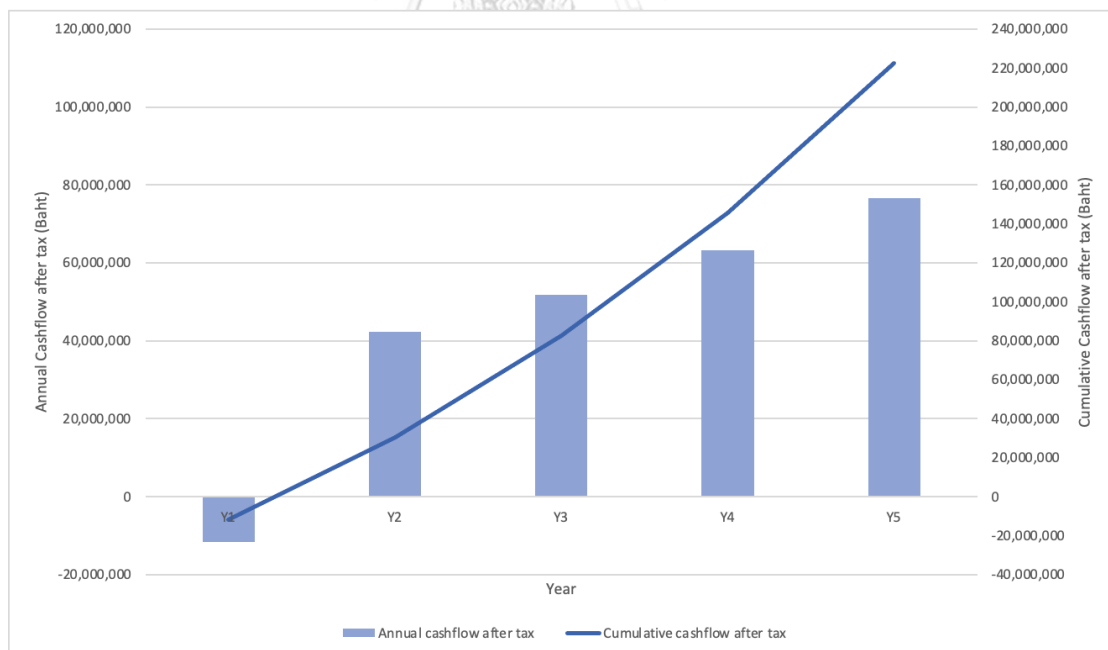


Figure 22 Cumulative Cash flow (Best case)

From Table 4 and Figure 22, at a discount rate of 10%, the 5-year NPV is 174,283,060.89 baht and the 5-year IRR is 447%. The duration of payback is 14.81 months.

5.6.2. Base Case

The sales start in Q4 of year 1 and expect for growth rate at 10% per year. The devices are sold at 800 Baht per piece.



Table 5 Cost Benefit Analysis (Base case)

	Y1	Y2	Y3	Y4	Y5
CAPEX	583,900.00	0.00	0.00	0.00	0.00
Application Development	583,900.00	0.00	0.00	0.00	0.00
OPEX	17,855,046.58	73,030,586.66	80,084,556.59	87,833,236.35	96,346,332.83
Sales, general and administration	2,505,000.00	2,951,130.00	3,088,357.55	3,231,966.17	3,382,252.60
Marketing	1,000,000.00	1,046,500.00	1,095,162.25	1,146,087.29	1,199,380.35
Device Production	13,820,909.38	68,596,065.72	75,456,031.56	83,001,686.04	91,302,316.56
O365	16,747.20	17,525.94	18,340.90	19,193.75	20,086.26
Certification	100,000.00	0.00	0.00	0.00	0.00
Cloud Storage	90,000.00	94,185.00	98,564.60	103,147.86	107,944.23
Office Rental	180,000.00	180,000.00	180,000.00	180,000.00	180,000.00
Electricity	18,000.00	18,000.00	18,000.00	18,000.00	18,000.00
Water	6,000.00	6,000.00	6,000.00	6,000.00	6,000.00
Maintenance	58,390.00	58,390.00	58,390.00	58,390.00	58,390.00
Other	60,000.00	62,790.00	65,709.74	68,765.24	71,962.82
Depreciation of CAPEX	128,780.00	128,780.00	128,780.00	128,780.00	128,780.00
Depre-Computer	12,000.00	12,000.00	12,000.00	12,000.00	12,000.00
Amor-Web Dev	116,780.00	116,780.00	116,780.00	116,780.00	116,780.00
Revenue	6,075,125.00	111,894,291.60	128,807,727.07	148,277,106.70	170,690,054.93
Devices	6,075,125.00	111,894,291.60	128,807,727.07	148,277,106.70	170,690,054.93

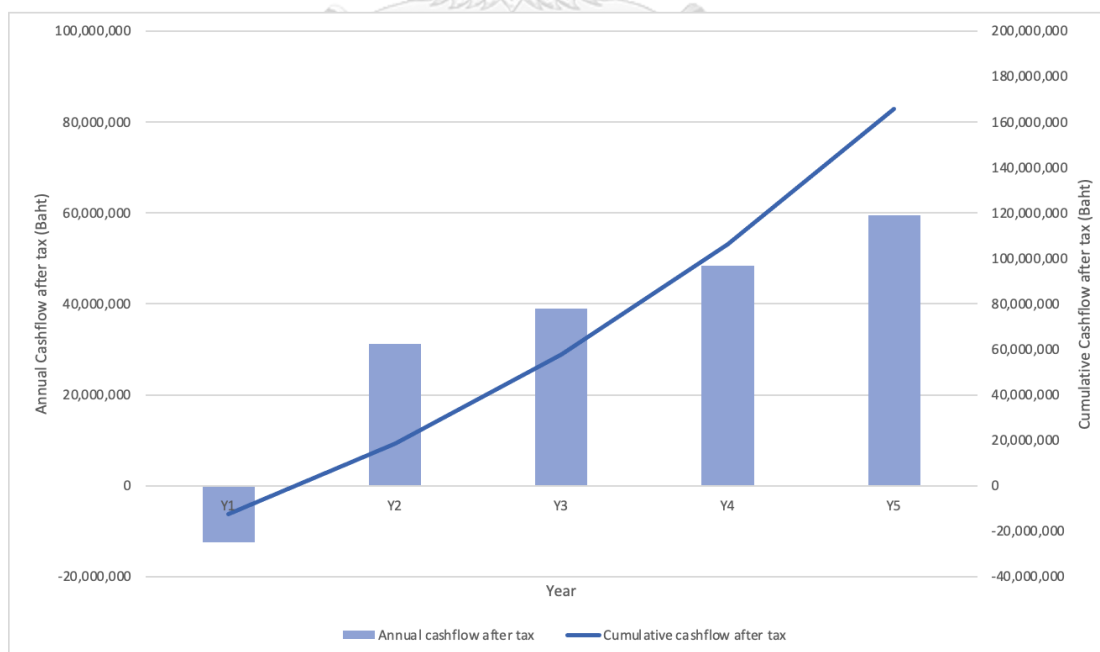


Figure 23 Cumulative Cash flow (Base case)

From Table 5 and Figure 23 ,at a discount rate of 10%, the 5-year NPV is 113,771,009.21 baht and the 5-year IRR is 273%. The duration of payback is 16.77 months.

5.6.3. Worst Case

The sales start in Q4 of year 1 and expect for growth rate at 10% per year. The devices are sold at 600 Baht per piece.

Table 6 Cost Benefit Analysis (Worst case)

	Y1	Y2	Y3	Y4	Y5
CAPEX	583,900.00	0.00	0.00	0.00	0.00
Application Development	583,900.00	0.00	0.00	0.00	0.00
OPEX	17,855,046.58	73,030,586.66	80,084,556.59	87,833,236.35	96,346,332.83
Sales, general and administration	2,505,000.00	2,951,130.00	3,088,357.55	3,231,966.17	3,382,252.60
Marketing	1,000,000.00	1,046,500.00	1,095,162.25	1,146,087.29	1,199,380.35
Device Production	13,820,909.38	68,596,065.72	75,456,031.56	83,001,686.04	91,302,316.56
O365	16,747.20	17,525.94	18,340.90	19,193.75	20,086.26
Certification	100,000.00	0.00	0.00	0.00	0.00
Cloud Storage	90,000.00	94,185.00	98,564.60	103,147.86	107,944.23
Office Rental	180,000.00	180,000.00	180,000.00	180,000.00	180,000.00
Electricity	18,000.00	18,000.00	18,000.00	18,000.00	18,000.00
Water	6,000.00	6,000.00	6,000.00	6,000.00	6,000.00
Maintenance	58,390.00	58,390.00	58,390.00	58,390.00	58,390.00
Other	60,000.00	62,790.00	65,709.74	68,765.24	71,962.82
Depreciation of CAPEX	128,780.00	128,780.00	128,780.00	128,780.00	128,780.00
Depre-Computer	12,000.00	12,000.00	12,000.00	12,000.00	12,000.00
Amor-Web Dev	116,780.00	116,780.00	116,780.00	116,780.00	116,780.00
Revenue	4,556,343.75	83,920,718.70	96,605,795.30	111,207,830.02	128,017,541.20
Devices	4,556,343.75	83,920,718.70	96,605,795.30	111,207,830.02	128,017,541.20

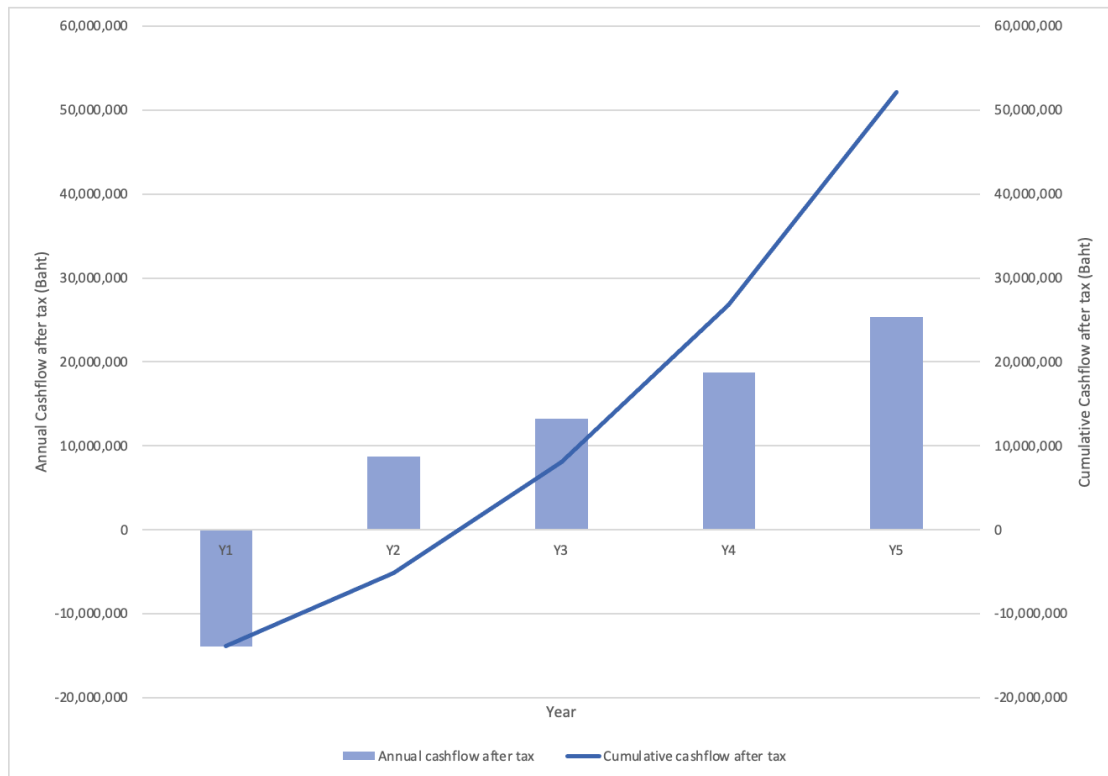


Figure 24 Cumulative Cash flow (Worst case)

From Table 6 and Figure 24, at a discount rate of 10%, the 5-year NPV is 33,088,273.64 baht and the 5-year IRR is 84%. The duration of payback is 31.07 months.

6. Discussion and Conclusion

6.1. Discussion

The peak flow meter is suggested by WHO and GINA for daily use by asthma patients in order to monitor symptoms and manage exacerbations. Even though the peak flow meter is compact, affordable, and portable, it only provides PEFr information. In comparison, the spirometer delivers more thorough lung information. However, it is expensive and difficult to carry, especially the conventional spirometer used in hospitals. The patient must visit the hospital to use it. On the global market, a smaller, more portable spirometer has been developed; nevertheless, it comes at a price that Thai people cannot afford. The portable spirometer combines the advantages of the standard spirometer and the peak flow meter. The newly developed, portable, and less expensive spirometer offers the physician with comprehensive information for treatment analysis and is adequate for the Thai market.

6.2. Conclusion

The prototype of the portable spirometer will be built of plastic in the shape of a cylinder and will contain a filter and circuit board. Users place a high value on hygiene; hence, the device must be easily detachable in order to replace or clean its components. Patients with asthma are urged by WHO and GINA to use the peak flow meter daily; a reminder function will be implemented. According to the survey, the portable spirometer should not cost more than 1,000 Thai Baht. Nevertheless, the price must be evaluated and tested for user acceptability during prototype testing.

With a device that is easily portable and monitors with the same accuracy as a spirometer, the patient may carry it without burden or difficulty. This will allow patients to check their lung function regularly. As a result of having complete information, the doctor will be able to effectively monitor the patient's status and alter the treatment. The size and market trend of this lung monitoring device comprises a

worldwide market with a large number of respiratory patients. In addition, with the polluted environment and pandemic occurred, the number of respiratory disease patients would continue to climb. Therefore, the market trend for this system and equipment is positive.

However, knowledge of lung monitoring devices is minimal on the Thai market. The significance of spirometry should be conveyed to the users.



Appendix A

Questionnaire

This survey was prepared as part of an Independent Study by a student of the master's degree in Technopreneurship and Innovation Management at Chulalongkorn University.

The purpose is to study the feasibility of Portable Spirometer Development

The information from the questionnaire will be kept confidential and used only for research purposes.

The questionnaire consists of 4 parts, which will take 3 - 5 minutes to complete.

Part 1 General information of participants

1. Age

- Under 20 years old
- 21 - 25 years old
- 26 - 35 years old
- 36 - 45 years old
- 46 - 55 years old
- 56 - 70 years old
- 71 years old and above

2. Gender

- Male
- Female
- LGBTQ+

3. Highest level of education

- Under High School/Vocational Certificate
- High School/Vocational Certificate
- High Vocational Certificate
- Bachelor's Degree
- Master's Degree

Doctor's Degree

4. Occupation

Student

Employee

Civil Servant/State Enterprise Employee

Business Owner

Freelance

Housewife

Others _____

5. Income per month

Below 15,000 THB

15,000 -34,999 THB

35,000 - 69,999 THB

70,000 - 99,999 THB

100,000 THB and above

6. Residence

Bangkok Metropolis and Vicinity

Upcountry – District area

Upcountry – not district area

7. Does user has Pulmonary disease?

Yes

No

Part 2 Purpose of Spirometer Usage

8. Has user ever know Peak Flow Meter/Spirometer?

Yes

No

9. Has user ever used Peak Flow Meter/Spirometer?

Yes

No

10. Whom does user require Peak Flow Meter/Spirometer for?

Self

Family member

Other _____

11. User requires Peak Flow Meter/Spirometer for which reason

Monitoring lung health

Monitoring respiratory system disease according to doctor's order

Follow up on lung health after being infected by COVID-19

Watch out for COVID-19 infection

Other _____



Part 3 Factors affecting Spirometer Selection

Portable Spirometer is a cylindrical bar device (Figure 25) with a circuit board in the cylinder. User could hold the device with a mouth as if preparing to suck the water from the tube, inhale, and blow air into the device. The device measures the exhalation and calculates lung health compared to the statistic. The calculated information will be displayed on the connected mobile phone.



Figure 25 Sample shape of the Portable Spirometer

12. Preferred type of connection

- Headphone Jack
- Bluetooth

13. Suitable type of material

- Plastic
- Glass
- Wood
- Other _____

14. Factors affecting device selection

Please rate the importance of each factor affecting device selection

1 means this factor has NO importance/impact in choosing a device

5 means this factor has HIGH importance/impact in choosing a device

a. Parts of a device can be changed/replaced for hygiene

Less important 1 2 3 4 5 Most Important

b. Easy to clean

Less important 1 2 3 4 5 Most Important

c. Easy to carry

Less important 1 2 3 4 5 Most Important

d. Data is automatically synced and stored in the connected mobile phone

Less important 1 2 3 4 5 Most Important

e. Remind user to use Spirometer to log data

Less important 1 2 3 4 5 Most Important

f. Lightweight

Less important 1 2 3 4 5 Most Important

g. Device is durable

Less important 1 2 3 4 5 Most Important

15. Preferred sanitisation method

Please rate the sanitisation method

1 means you are strongly disagree to use this method

5 means you are strongly agree to use this method

a. Parts are removable and replaceable ex. Filter

Strongly Disagree 1 2 3 4 5 Strongly Agree

b. Parts are removable and washable

Strongly Disagree 1 2 3 4 5 Strongly Agree

c. Spray alcohol to clean the device/parts

Strongly Disagree 1 2 3 4 5 Strongly Agree

d. Boil to clean the parts

Strongly Disagree 1 2 3 4 5 Strongly Agree

e. Other preferred sanitisation method _____



Part 4 Price Expectation

16. Preferred purchasing plan

- State Welfare
- One-time purchase (Go to question no. 2)
- Subscription (Go to question no. 3)

17. Acceptable price for one-time purchase

- Under 100 THB
- 100 – 250 THB
- 251 – 500 THB
- 501 – 1,000 THB
- More than 1,000 THB
- Other _____

18. Acceptable price for subscription per month

- Under 60 THB
- 61 – 100 THB
- 101 – 150 THB
- 151 – 250 THB
- More than 250 THB
- Other _____

19. Suggestion



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Appendix B

Index of Item-Objective Congruence (IOC)

Instructions

1. This survey was prepared as part of an Independent Study by a student of the master's degree in Technopreneurship and Innovation Management at Chulalongkorn University. The purpose is to study the feasibility of Portable Spirometer Development
2. This survey intend to evaluate the validity of the questionnaire using Index of item objective congruence: IOC
3. The questionnaire contains 4 parts:
 - Part 1 General Information
 - Part 2 Purpose of spirometer usage
 - Part 3 Factors affecting spirometer selection
 - Part 4 Price Expectation
4. The Item-Objective Congruence (IOC) was used to evaluate the questionnaire items based on the score range from -1 to +1.
 - 1) Congruent = + 1
 - 2) Questionable = 0
 - 3) Incongruent = -1
5. By putting a recommendation in the space provided, the researcher would like to solicit additional suggestions or viewpoints from experts and specialists

With gratitude,

Chawanrat Trekarjanavong

Student of Technopreneurship and Innovation Management

Chulalongkorn University

Index of Item Objective Congruence: IOC

Topic : Feasibility of Portable Spirometer Development

Part 1 General Information

Targeted group General population interested in monitoring lung health

No.	Detail	Validity			IOC Score
		Congruent +1	Questionable 0	Incongruent -1	
1	Age <input type="checkbox"/> Under 20 years old <input type="checkbox"/> 21 - 25 years old <input type="checkbox"/> 26 - 35 years old <input type="checkbox"/> 36 - 45 years old <input type="checkbox"/> 46 - 55 years old <input type="checkbox"/> 56 - 70 years old <input type="checkbox"/> 71 years old and above	3			1
2	Gender <input type="checkbox"/> Male <input type="checkbox"/> Female <input type="checkbox"/> LGBTQ+	3			1
3	Highest level of education <input type="checkbox"/> Under High School/Vocational Certificate <input type="checkbox"/> High School/Vocational Certificate <input type="checkbox"/> High Vocational Certificate <input type="checkbox"/> Bachelor's Degree <input type="checkbox"/> Master's Degree <input type="checkbox"/> Doctor's Degree	3			1
4	Occupation <input type="checkbox"/> Student <input type="checkbox"/> Employee <input type="checkbox"/> Civil Servant/State Enterprise Employee <input type="checkbox"/> Business Owner <input type="checkbox"/> Freelance <input type="checkbox"/> Housewife	3			1

No.	Detail	Validity			IOC Score
		Congruent +1	Questionable 0	Incongruent -1	
	<input type="checkbox"/> Others _____				
5	Income per month <input type="checkbox"/> Below 15,000 THB <input type="checkbox"/> 15,000 -34,999 THB <input type="checkbox"/> 35,000 - 69,999 THB <input type="checkbox"/> 70,000 - 99,999 THB <input type="checkbox"/> 100,000 THB and above	3			1
6	Residence <input type="checkbox"/> Bangkok Metropolis and Vicinity <input type="checkbox"/> Upcountry – District area <input type="checkbox"/> Upcountry – not district area	3			1
7	Does user has Pulmonary disease? <input type="checkbox"/> Yes <input type="checkbox"/> No	2	1		0.67

Part 2 Purpose of spirometer usage

Spirometer usage To determine if respondents are familiar with or have ever used a lung monitoring device.

Purpose of usage To identify target group and reason of using the spirometer

No.	Detail	Validity			IOC Score
		Congruent +1	Questionable 0	Incongruent -1	
8	Has user ever know Peak Flow Meter/Spirometer? <input type="checkbox"/> Yes <input type="checkbox"/> No	3			1

No.	Detail	Validity			IOC Score
		Congruent +1	Questionable 0	Incongruent -1	
9	Has user ever used Peak Flow Meter/Spirometer? <input type="checkbox"/> Yes <input type="checkbox"/> No	3			1
10	Whom does user require Peak Flow Meter/Spirometer for? <input type="checkbox"/> Self <input type="checkbox"/> Family member <input type="checkbox"/> Other _____	3			1
11	User requires Peak Flow Meter/Spirometer for which reason <input type="checkbox"/> Monitoring lung health <input type="checkbox"/> Monitoring respiratory system disease according to doctor's order <input type="checkbox"/> Follow up on lung health after being infected by COVID-19 <input type="checkbox"/> Watch out for COVID-19 infection <input type="checkbox"/> Other _____	3			1

Part 3 Factors affecting spirometer selection

Device Characteristic To determine the characteristics of device and mobile phone connectivity that consumers desire and are willing to use, as well as the materials that consumers deem suitable for the construction of lung monitoring devices.

Factors affecting spirometer selection Separated into device features that customers consider when selecting a device and consumer-preferred cleaning procedures, as cleaning methods are crucial for preventing the spread of infectious diseases.

No.	Detail	Validity			IOC Score
		Congruent +1	Questionable 0	Incongruent -1	
12	Preferred type of connection <input type="checkbox"/> Headphone Jack <input type="checkbox"/> Bluetooth	3			1
13	Suitable type of material <input type="checkbox"/> Plastic <input type="checkbox"/> Glass <input type="checkbox"/> Wood <input type="checkbox"/> Other _____	3			1
14	Factors affecting device selection				
	Parts of a device can be changed/replaced for hygiene	3			1
	Easy to clean	3			1
	Easy to carry	3			1
	Data is automatically synced and stored in the connected mobile phone	3			1
	Remind user to use Spirometer to log data	3			1
	Lightweight	3			1
	Device is durable	3			1
15	Preferred sanitisation method				
	Parts are removable and replaceable ex. Filter	3			1

No.	Detail	Validity			IOC Score
		Congruent +1	Questionable 0	Incongruent -1	
	Parts are removable and washable	3			1
	Spray alcohol to clean the device/parts	3			1
	Boil to clean the parts	2	1		0.67
	Other preferred sanitisation method _____	3			1

Part 4 Price Expectation

To examine purchasing model and the acceptable price

No.	Detail	Validity			IOC Score
		Congruent +1	Questionable 0	Incongruent -1	
16	Preferred purchasing plan <input type="checkbox"/> State Welfare <input type="checkbox"/> One-time purchase (Go to question no. 17) <input type="checkbox"/> Subscription (Go to question no. 18)	2	1		0.67
17	Acceptable price for one-time purchase <input type="checkbox"/> Under 100 THB <input type="checkbox"/> 100 – 250 THB <input type="checkbox"/> 251 – 500 THB <input type="checkbox"/> 501 – 1,000 THB <input type="checkbox"/> More than 1,000 THB <input type="checkbox"/> Other _____	3			1
18	Acceptable price for subscription per month <input type="checkbox"/> Under 60 THB <input type="checkbox"/> 61 – 100 THB <input type="checkbox"/> 101 – 150 THB <input type="checkbox"/> 151 – 250 THB <input type="checkbox"/> More than 250 THB <input type="checkbox"/> Other _____	2	1		0.67
19	Other Suggestions				

Part 5 Suggestion

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จุฬาลงกรณ์มหาวิทยาลัย
CHULALONGKORN UNIVERSITY

VITA

NAME ชวัลรัตน์ ตริกาญจนวงศ์
DATE OF BIRTH 26 มีนาคม 2533
INSTITUTIONS ATTENDED วิทยาศาสตร์บัณฑิต จุฬาลงกรณ์มหาวิทยาลัย

