รายงานวิจัยฉบับสมบูรณ์

โครงการพัฒนาและการใช้งานไทยแอปพลิเคชันเพื่อคัดแยกอาการป่วย

โดยผู้ช่วยศาสตราจารย์ ดร. อรวิชย์ ถิ่นนุกูล

15 กันยายน 2563

สัญญาเลขที่ MRG 6280049

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มหาวิทยาลัยเชียงใหม่

สนับสนุนโดยสำนักงานกองทุนสนับสนุนการวิจัย
และ
สำนักงานคณะกรรมการการอุดมศึกษา

Abstract

Project Code : MRG 6280049

Project Title : Development and Implementation of Thailand Triage Mobile Application

Investigator : Assistant Professor Dr. Orawit Thinnukool Chiang Mai University

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Project Period : 1 March 2018- 28 February 2021 (2Years)

Background:

The medical personnel, especially the primary care doctors could effectively manage and forward patient in the correct order to suit the resources and medication available. Before admitting patients into the emergency department, the pre-hospital process is important both in terms of treatment performance and requesting resources from an emergency unit. The existing system to triage patients in Thailand is not functioning optimally in either the primary medical system or pre-hospital treatment. Areas that contain shortcomings include speed, features, and appropriate systems. There is a high possibility of misrepresenting false Initial Dispatch Code (IDC) which causes over or under utilizing emergency resources, such as rescue teams, community hospitals and emergency medical volunteers.

Research Objective: 1) This research project aiming to develop the functionally designed mobile application which can provide suitable use for patient triage based on the Criteria Based Dispatch (CBD). 2) Patient triage system Development for supporting the resources management operation of dispatch centres and rescue teams.

Methods: In the application development, usability system design has been applied together with system reliability test, to optimize the pre-hospital processes specifically to sort patients by using IDC improving request for emergency resources. The development of a triage mobile application has been conducted on both iOS and Android operating systems to support patient triage based on the Criteria Based Dispatch (CBD). The 25 main symptom categories covered by CBD were used to design and develop the application, and 12 emergency medical staff including doctors and nurses were subjected to test the system whereas 68 volunteers from active members of rescue teams in Chiang Mai and Lampang were recruited to test the patient triage system.

Results: The application development result shows the comparison between the proposed triage application and staff experience. The triage reliability test implies that the time used to triage by experienced staff, in non-trauma cases, is slower than using the application. For the usability test, the result shows that the application functions are more effective in the emergency operations and correction of IDC code representation. Whereas the result of system report in cases where the system had been implemented, it was found to determine the frequency of symptoms, the time period during which cases occurred, and the density of cases in each area.

Conclusions: The triage application will be utilized to support the pre-hospital process and to classify patient conditions before admitting patients to the Emergency Department (ED). The application is suitable for users who are not medical emergency staff. Patients with non-trauma symptoms may be a suitable group to use the application in terms of time used to identify IDC for their own symptoms. In terms of application use, it can provide benefits to those who want to self-identify their symptoms before requesting medical services. This project can result in the overall development both triage application and patient triage system of primary care medical team to gain more knowledge by using this application, which is in agreement with the 20-year national strategic plan on public health innovation, in accordance with the government policy to bring Thailand to Thailand 4.0.

Keywords: Triage, emergency medical service, primary medical, web based, dispatch centre.

บทคัดย่อ

รหัสโครงการ : MRG 6280049

ชื่อโครงการ: การพัฒนาและการใช้งานไทยแอปพลิเคชันเพื่อคัดแยกอาการป่วย

ชื่อนักวิจัย: ผู้ช่วยศาสตราจารย์ ดร. อรวิชย์ ถิ่นนุกูล มหาวิทยาลัยเชียงใหม่

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ที่มาและความสำคัญ: บุคลากรหรือเจ้าหน้าที่ที่ปฏิบัติหน้าที่ทางการแพทย์ปฐมภูมิ เป็นกลุ่มที่สามารถจัดการและส่งต่อผู้ป่วยได้อย่างมีประสิทธิภาพตามลำดับที่ถูกต้องเพื่อให้เหมาะสมกับทรัพยากรที่มีอยู่ก่อนที่จะรับผู้ป่วยเข้าแผนกฉุกเฉิน กระบวนการส่งต่อเข้าโรงพยาบาลมีความสำคัญอย่างยิ่ง ทั้งในแง่ของประสิทธิภาพการรักษาและการจัดเตรียมหรือการขอรอทรัพยากรจากหน่วยฉุกเฉิน ระบบที่มีอยู่ในการตรวจคัดแยกผู้ป่วยในประเทศไทย อาจไม่สามารถทำงานได้อย่างเหมาะสม ทั้งในการให้บริการทางการแพทย์ปฐมภูมิ หรือจัดการก่อนการรักษาในโรงพยาบาล ซึ่งอาจมีข้อบกพร่องที่เกิดขึ้นจากการทำงาน ด้านความรวดเร็วในการให้บริการ หรือเอื้ออำนวยให้เกิดการปฏิบัติหน้าที่ที่เหมาะสมได้ รวมถึงการเข้าถึงตำแหน่งเกิดเหตุ จึงมีความเป็นไปได้ที่จะเกิดการคัดแยกผู้ป่วยโดยการใช้รหัส Initial Dispatch Code (IDC) เพื่อร้องขอทรัพยากรเพื่อรองรับเหตุฉุกเฉินมากเกินไปหรือน้อยเกินจากความเป็นจริง โดยการทำหน้าที่ของ ทีมกู้ภัย เจ้าหน้าที่โรงพยาบาลชุมชนและอาสาสมัครการแพทย์ฉุกเฉิน ซึ่งส่งผลต่อประสิทธิภาพการให้บริการและการใช้ทรัพยากรที่เกินความจำเป็น ส่งผลโดยตรงต่องบประมาณ และการบริหารจัดการในภาพรวมได้

วัตถุประสงค์: 1) เพื่อพัฒนาแอปพลิเคชันที่ออกแบบมาเพื่อการใช้งานที่เหมาะสมสำหรับการตรวจผู้ป่วยโดยพิจารณาจากเกณฑ์ลำดับการคัดแยกอาการของผู้ป่วย Criteria Based Dispatch (CBD)
2) เพื่อพัฒนาระบบสั่งการที่เชื่อมต่อกับแอปพลิเคชันเพื่อการบริหารจัดการทรัพยากร

วิธีการดำเนินการวิจัย: ในการพัฒนาแอปพลิเคชันการออกแบบระบบการใช้งานได้ถูกทดสอบความถูกต้องสำหรับการคัดแยกอาการเจ็บป่วย เพื่อเพิ่มประสิทธิภาพกระบวนการก่อนเข้าโรงพยาบาลโดยเฉพาะเพื่อคัดแยกผู้ป่วยโดยการออกรหัสสั่งการ IDC ในการปรับปรุงคำขอทรัพยากรฉุกเฉินที่เหมาะสมนั้น การพัฒนาแอปพลิเคชัน Triage ได้ดำเนินการบนระบบปฏิบัติการ iOS และ Android เพื่อรองรับรูปแบบมาตรฐานการคัดแยกอาการเจ็บป่วย Criteria Based Dispatch (CBD) ซึ่งมีกลุ่มอาการหลัก 25 ประเภทที่ครอบคลุมโดยแอปพลิเคชันและเจ้าหน้าที่การแพทย์ฉุกเฉิน 12 คน ในขณะที่การทดสอบการทำงานของระบบคัดแยกผู้ป่วย ใช้อาสาสมัครจำนวน 68 คนจากสมาชิกของอาสาสมัครฉุกเฉินในเขตจังหวัดเชียงใหม่และลำปางในการทดสอบระบบ

ผลลัพธ์: ผลจากการทดสอบ แสดงการเปรียบเทียบประสิทธิภาพการใช้งานระหว่างแอปพลิเคชัน และการคัดแยกด้วยประสบการณ์ของผู้ปฏิบัติงานด้านการแพทย์ฉุกเฉิน พบว่า แอปพลิเคชันใช้ระยะเวลาในการคัดแยกอาการเจ็บป่วยได้ดีกว่าการใช้ประสบการณ์ ในกลุ่มอาการที่ไม่ใช้เหตุฉุกเฉิน และได้รหัสสั่งการที่แม่นยำกว่า ในขณะที่กรณีสำหรับเหตุฉุกเฉิน ประสบการณ์ของผู้ปฏิบัติงานด้านการแพทย์ฉุกเฉินใช้ระยะเวลาใน

การคัดแยกน้อยกว่าการใช้ แอปพลิเคชัน แต่รหัสสั่งการนั้นร้องขอเกินกว่าความเป็นจริง ในขณะที่การใช้งานระบบคัดแยกผู้ป่วยที่เชื่อมโยงการทำงานจากแอปพลิเคชันช่วยให้ ฝ่ายอำนวยการรับแจ้งเหตุ ได้รับข้อมูลการร้องขอทรัพยากร ข้อมูลความถี่การเกิดเหตุ ช่วงเวลา ความหนาแน่นของพื้นที่ได้

สรุปผล: แอปพลิเคชัน Triage มีความเหมาะสมใช้เพื่อสนับสนุนกระบวนการก่อนเข้าโรงพยาบาล สำหรับการจำแนกอาการเจ็บของผู้ป่วยก่อนการนำส่งโรงพยาบาลในแผนกฉุกเฉิน (ED) แอปพลิเคชันนี้เหมาะสำหรับ ผู้ปฏิบัติหน้าที่ด้านการแพทย์ฉุกเฉินปฐมภูมิสำหรับการใช้งานเพื่อเป็นเครื่องมือเพื่อการคัดแยกอาการเจ็บป่วยเบื้องต้นก่อนการส่งต่อได้ นอกจากนี้ ผลลัพธ์ที่ได้จากการใช้แอปพลิเคชันสำหรับผู้ใช้งานทั่วไป ช่วยให้คัดแยกอาการเจ็บป่วยของตนเองได้ และสามารถประเมินความอาการ ว่าเข้าข่ายเหตุฉุกเฉินเพื่อการส่งต่อการรักษาหรือขอรับบริการทางการแพทย์มากน้อยเพียงใด

ผลลัพธ์ที่ได้จากงานวิจัยนี้ส่งผล และสนับสนุนให้การพัฒนาปฏิบัติหน้าที่ด้านการแพทย์ฉุกเฉินปฐมภูมิ สามารถคัดแยกผู้ป่วยได้มีประสิทธิภาพมากยิ่งขึ้น ทั้งยังสามารถบริหารจัดการทรัพยากรของภาครัฐที่มีอยู่อย่างจำกัดให้สามารถใช้งานอย่างมีประสิทธิภาพมากยิ่งขึ้น ตลอดจนระบบที่พัฒนาขึ้นรองรับการทำงานกับระบบเดิมของสถาบันการแพทย์ฉุกเฉิน ซึ่งสอดคล้องกับแผนยุทธศาสตร์ชาติระยะ 20 ปีด้านนวัตกรรมด้านสาธารณสุขตามนโยบายรัฐบาลที่จะนำพาประเทศไทยสู่ประเทศไทย 4.0.

คำหลัก: การคัดแยกผู้ป่วย, บริการการแพทย์ฉุกเฉิน, การรักษาเบื้องต้น, เว็บเบส, ศูนย์รับแจ้งเหตุฉุกเฉิน

เอกสารแนบหมายเลข 3

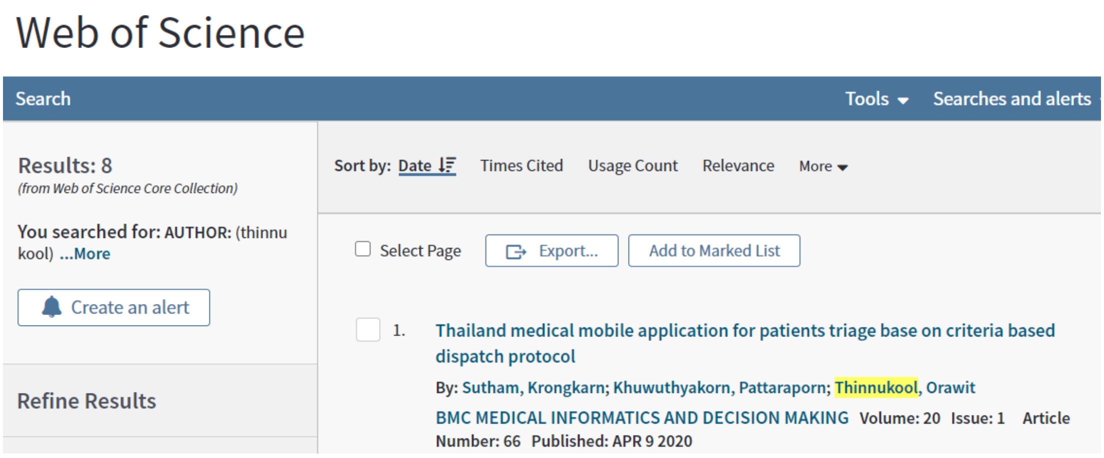
Output จากโครงการวิจัยที่ได้รับทุนจาก สกว.

1. **ผลงานตีพิมพ์ในวารสารวิชาการนานาชาติ (ระบุชื่อผู้แต่ง ชื่อเรื่อง ชื่อวารสาร ปี เล่มที่ เลขที่ และหน้า) หรือผลงานตามที่คาดไว้ในสัญญาโครงการ**

   - ผลงานทางวิชาการจำนวน 1 เรื่อง ตามสัญญาโครงการ

   Sutham, K., Khuwuthyakorn, P. & **Thinnukool, O**. Thailand medical mobile application for patients triage base on criteria based dispatch protocol. BMC Med Inform Decis Mak 20, 66 (2020). https://doi.org/10.1186/s12911-020-1075-6 Impact factor 2.067 Indexed Web of Science Quartiles 3.

   และ SJR (Scopus) Quartiles 1

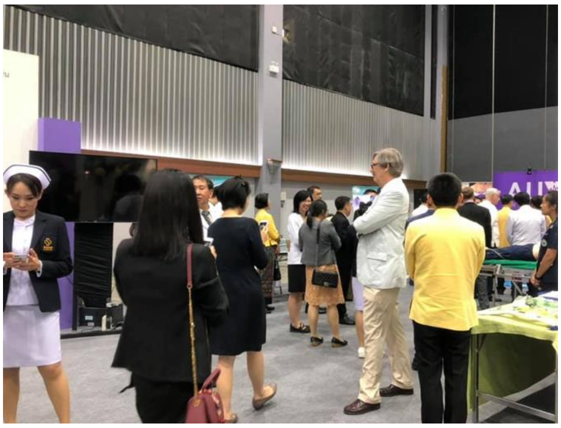


2. **การนำผลงานวิจัยไปใช้ประโยชน์**

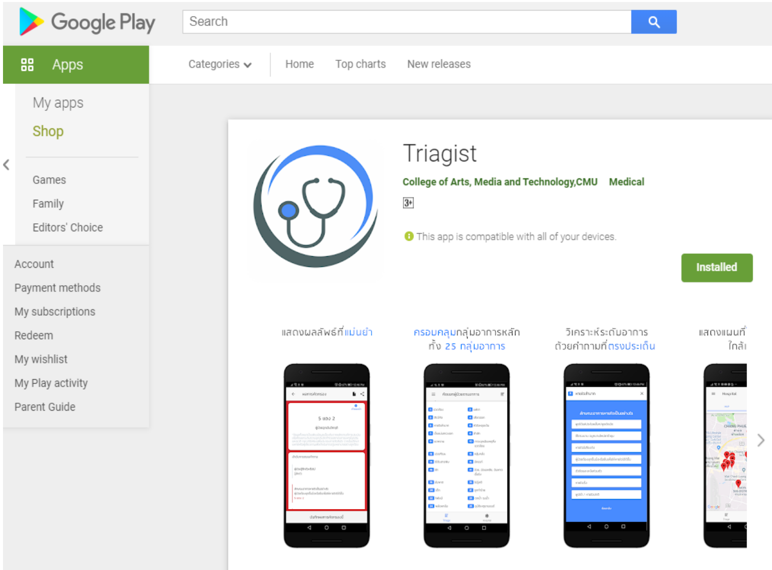
   - **การนำไปใช้งานเชิงสาธารณะ**

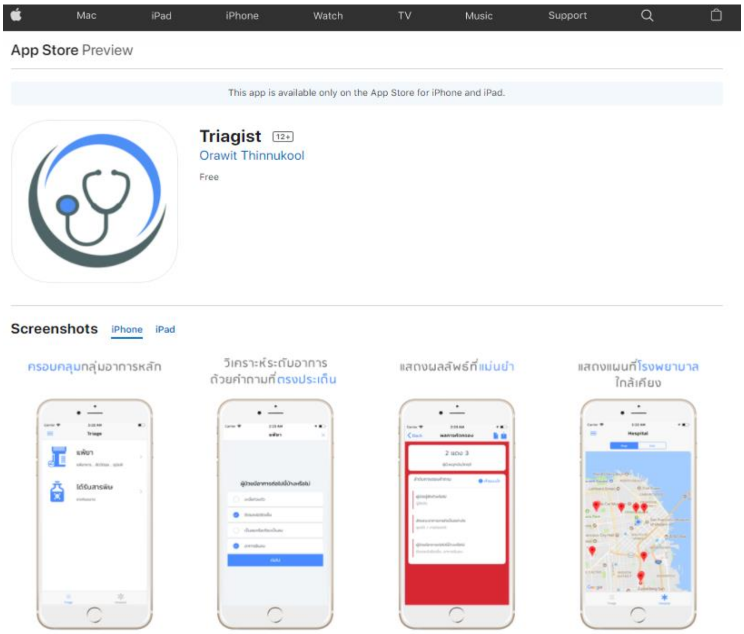
     ในการพัฒนาแอปพลิเคชันเพื่อการคัดแยกอาการผู้ป่วยนี้ เป็นการสร้างนวัตกรรมทางแพทย์สมัยใหม่ที่ให้ทุกคนเข้าถึงได้ง่าย ช่วยให้การบริการทางการแพทย์ฉุกเฉินที่ดีและมีประสิทธิภาพมากขึ้น โดยหลังจากที่มีการพัฒนาและตรวจสอบประสิทธิภาพระบบแล้วเสร็จ มีการกระจายการใช้งานนำไปสู่ผู้ปฏิบัติการการแพทย์ฉุกเฉินปฐมภูมิ ประกอบด้วย อาสาสมัคร กู้ภัย หรือร่วมอาสา ในเขตจังหวัดเชียงใหม่ ที่ได้เข้าร่วมอบรมด้านเวชศาสตร์ฉุกเฉินโดย ภาควิชาเวชศาสตร์ฉุกเฉิน คณะแพทยศาสตร์ มหาวิทยาลัยเชียงใหม่ เพื่อสร้างผลกระทบ และยกระดับความรู้ให้กับกลุ่มดังกล่าวในการเพิ่มคุณภาพด้านการปฏิบัติงาน ได้โดยเฉพาะอย่างยิ่งการคัดแยกผู้ป่วยซึ่งต้อง วินิจฉัยอาการอย่างรวดเร็ว เพื่อจัดเตรียมและร้องขอทรัพยากรที่เหมาะสมต่อเหตุ

- ระบบที่พัฒนาถูกนำไปเผยแพร่ในงาน มหกรรมสุขภาพ 60 ปี คณะแพทยศาสตร์ มหาวิทยาลัยเชียงใหม่ ซึ่งเป็นงาน ที่จัดเพื่อให้ประชาชนทั่วไป นักวิชาการ บุคลากรทางการแพทย์ระดับต่าง ๆ ได้เข้าชมความก้าวหน้าด้านนวัตกรรมทางการแพทย์ การบริการ และวิธีการรักษาสมัยใหม่ ซึ่งแอปพลิเคชันเพื่อการคัดแยกผู้ป่วยนี้ ได้นำเสนอในโซนนิทรรศการของภาควิชาเวชศาสตร์ฉุกเฉิน



- นอกจากนี้แอปพลิเคชันเพื่อการคัดแยกอาการ ถูกเผยแพร่และปรับปรุงในเวอร์ชันที่ 2 ในระบบ Android ให้มีความถูกต้องในกระบวนการคัดแยกอาการมากขึ้น นอกจากการให้อาสาสมัคร หรือผู้สนใจดาวน์โหลดใช้งานโดยตรงจาก การอบรมให้ความรู้ ยังมีการเผยแพร่เพื่อให้ผู้สนใจ หรือผู้ใช้งานอื่นๆ ที่ไม่อยู่ในจังหวัดเชียงใหม่ หรือ กลุ่มตัวอย่างในโครงการวิจัยได้ใช้งานในวงกว้างมากขึ้น โครงการวิจัยจึงเผยแพร่แอปพลิเคชันในชื่อ Triagist ใน Google Play Store และ Apple Store





3. อื่น ๆ (เช่น ผลงานตีพิมพ์ในวารสารวิชาการในประเทศ การเสนอผลงานในที่ประชุมวิชาการ หนังสือ การจดสิทธิบัตร)
   - ไม่มี

Research output: Part 1 Mobile Application Development for Patients Triage

1. Background

The application of smart technology has become an increasingly common practice in daily life, especially in medical treatment. Modern smart technology facilitates faster computation, has natural-command abilities, wider presentation screens and intelligent operation [1-4]. Advanced smart technology has also been found to be widely used in medical healthcare; for example, in monitoring patients, tracing their health conditions, consultations by experts or doctors, obtaining suggestions related to healthcare medication, and much more. [5-6]. The number of people who need to consult doctors or receive medical services could be reduced by substituting new technology as an alternative [7-8].

Although the trend of using smart technology in healthcare has increased on a global scale, thereby reducing the duties of medical staff, inadequate public health support and services are still problematic in Thailand. While applications of smart technology have been developed in an effort to ease the overcrowding of emergency care units, this has not solved all their operational problems.

According to the National Bureau of Statistics, there were 220 million out-patients in Thailand in 2018, who were served by 35,388 doctors, 180,589 service providers and various other hospital staff [9]. Based on these numbers, the Thai healthcare system should be better at aiding primary care doctors. An effective primary care regime should include a self-care system, a long-distance patient care system, an effective patient-screening system, and a channel to deliver self-care knowledge to alleviate the workload of the public health units. Technology could be used to effectively manage medical personnel, especially primary care doctors, and patients could be treated in the order of the available resources and medication. These are the key elements of the national strategic plan for public health, which will be implemented over 20 years based on policy 4.0 [10] of the Thai government.

However, the disproportion between doctors and patients is causing concern. There are many reasons for overcrowding in hospitals across Thailand; for example, it can be difficult to predict the symptoms of a disease, side effects are sometimes unclear and patients involved in an accident often require a quick assessment. Primary care physicians play an important role in assessing patients in order to provide them with appropriate and timely medical services, both for normal illnesses and emergencies [11-12].

Pre-hospital information provided by rescue teams, rescuers, community hospitals and emergency medical volunteers is invalid in many cases due to the incorrect Initial Dispatch Code (IDC), which leads to over-allocating or under-allocating emergency resources. The National Institute of Emergency Medicine of Thailand has reported that 60% of the patients who come to the Emergency Department (ED) do not require urgent treatment. This issue especially occurs in regions in which patients need immediate care from medical providers because they lack confidence in their access to primary care [13-14]. As a result, many patients are admitted to an emergency room, which leads to the overcrowding of emergency care units, including the Out Patient Department (OPD) and the ED. Therefore, an effective patient assessment during the pre-hospital process could reduce the overcrowding in hospitals. For example, in an emergency, the rescue teams, rescuers, community hospitals and emergency medical volunteers are responsible for assessing and analysing patients and requesting all the necessary emergency resources. When these medical professionals and volunteers have no experience of making a comprehensive health assessment, the classification of patients using Criteria Based Dispatch (CBD) could be misrepresented, leading to an incorrect IDC and the over- or under-utilisation of emergency resources.

The best way to correctly assess a potential patient is to ask the provincial emergency command unit CBD questions, which results in an IDC. This process can take at least 2-3 minutes or more by phone. When an IDC is identified, the provincial emergency command unit requests an emergency dispatch from the nearest hospital to collect the patient. Trying to reduce the time and optimise the performance of the pre-hospital process is a continuous challenge for the National Institute for Emergency Medicine of Thailand (NIEM). The systematic patient assessment programme it developed, which is currently used for patient assessment to triage patients for IDC, has been found to be too difficult to use because a computer is required to run the programme (Microsoft Access) and this is impractical for primary emergency medical unit operations. Hence, it is only used by the provincial emergency command units, which are the central emergency units. Due to its inefficiencies, this system can only be leveraged in central call centres and is not used in the field.

Moreover, most Thai medical doctors use imported medical applications. Popular systems like the Canadian Triage mobile application and the Mobile Emergency Severity Index (ESI), are the standard for the emergency medical service in Thailand. These applications are widely used by medical doctors for patient triage because they simplify triage protocol referencing by providing a mobile interface. Based on the results of the study, mobile applications may have improved benefits for medical professionals and volunteers experienced in triage [15]. However, these applications are restricted to users with medical knowledge due to their advanced medical terminology. This is important, since the pre-hospital process not only involves medical staff, but also volunteers with limited medical knowledge.

The purpose of this paper is to determine the kind of system that can provide optimal patient triaging for requesting an accurate IDC. Additionally, it is important to find a practical solution for real-life operations by rescue teams, rescuers, community hospitals and emergency medical volunteers.

Moreover, there are other concerns that should be considered when developing an optimised medial system, such as how the system can reduce the overcrowding of the ED, how it can increase patients' knowledge when they discover suspicious symptoms, and whether they can assess those symptoms to determine if they need urgent treatment when they are at home.

Therefore, an ideal system is one that both primary care physicians and patients can use to screen illnesses in both normal and emergency cases. It should also be able to refer patients to appropriate emergency medical services by helping them to assess the severity of their symptoms and the need for urgent treatment. The system should enable patients to classify symptoms according to international standards.

The aim of this research it to develop a mobile medical application which is suitable for use in Thailand based on the aforementioned requirements. This application must be capable of enabling patients to triage medical conditions based on dispatch protocol-grade criteria. It must be suitable for use on mobile devices because it will serve as a tool for both primary emergency medical practitioners and general users. A prototype will be developed in this study by using patients' assessment data from the NIEM.

This application is expected to reduce the limitations of existing systems that require specialised knowledge to effectively triage patients.

1.1 Triage Medical System

The use of technology via smart devices has transformed many aspects of the clinical practices of healthcare professionals. Mobile devices such as tablets are now commonly used in healthcare, which has led to the rapid development of medical software applications (apps). Mobile technology plays a significant role in terms of patient care by enabling users to track their health condition and suggesting suitable medication, as well as providing tools for medical providers to monitor their patients [16-17].

The use of systems based on smartphones facilitates the effective tracking and managing of patients' health [18-21]. A variety of research that has been conducted in relation to applications associated with emergency cases will be discussed in this section.

The incorporation of information technology into the worldwide medical field via smartphones has become increasingly common due to its accuracy. For example, based on Scott's study, the application of electronic triage increased the accuracy of the triage protocol. The probability of clinical care, emergency surgery and hospitalisation was indicated when applying the e-triage predictor and algorithms [22].

Tadahiro recently developed a system to optimise emergency department operations. Since the prediction of the ED disposition at the triage level remains challenging, this system is expected to enhance it, as well as improve the ability to predict the disposition of patients and support various medical duties [23].

Lei and his team studied the use of triage to identify patients who require immediate resuscitation, assign them to a pre-designed patient care area, and administer the appropriate diagnostic/therapeutic measures based on the use of ESI in a paediatric emergency room. According to the results, nurses improved their performance, taking approximately 2 minutes for triage, which was similar to that of doctors for ESI. Patients in levels 1-3, who require immediate, life-saving intervention without delay are at great risk of deterioration due to time-critical problems. This causes an urgent demand for resources to investigate and treat them and, according to the findings of this study, nurses are able to identify severe paediatric cases [24-25].

Moreover, triage mobile applications have been developed and applied to dental science. For instance, Corey developed a mobile application for triaging dental emergencies based on the need to analyse and assess captured intraoral images [26]. Patients are able to self-identify their dental problem and complete a triage report within 4 minutes by selecting the most appropriate scenario that describes their discomfort. This application helps both dentists and patients to save time prior to a visit.

In Thailand, Sumrumeram developed a medical application that can track high-risk stroke and stemi patients who need time-sensitive Emergency Medical Services (EMS) [27]. This application can be operated on both Android and iOS systems and a Global Positioning System (GPS) Tracker is used to indicate the transmitter's real-time location. The researchers studied the use of a GPS Tracker through GPS satellites and transmissions over the 3G mobile phone network with a focus on programming to integrate them with the system for semi-automatic usage. The programme was tested in urban areas where there was Internet access to enable the system to accurately locate patients. This study provided further assurance that emergency medical services could be optimised by the application of information technology for the benefit of patient safety.

Ruangtananurak developed an emergency alert system including maps for the positioning of emergency medical services [28]. Victims or witnesses of an accident can use this application on a smart phone to send information from the scene, such as the location or other salient information, to emergency centres in the area so that the Emergency Medical Services (EMS) can quickly dispatch emergency ambulances to the right location. It also includes directions to the nearest hospital.

As can be seen from the aforementioned examples [24-28], mobile-based systems can optimise triage by enabling severe medical cases to be identified quickly for accurate and immediate intervention. However, patients should also be able to describe and determine the severity of their symptoms based on the proposed mobile application and it should contain a function to sort symptoms based on the Thai dispatch standard.

1.2 Thai Triage Standard

Triage is a process that involves determining and prioritising patients' treatment based on the severity of their condition to facilitates the efficient use of limited resources. It may also be used when patients arrive at the emergency department or in telephone medical advice systems [29] and, according to the National Institute for Emergency Medicine [30-32], it can increase the accuracy of the pre-hospital process by reducing the subjectivity of an initial diagnosis.

The criteria-based initial dispatch code used as the standard in Thailand is based on 25 main categories of patients' signs and symptoms (National Institute for Emergency Medicine [30][33]. This CBD protocol enables the status of patients who request pre-hospital resources to be rapidly identified as unstable or "sick" [34] by questioning them in an interview and assigning them one of five colour codes. The IDC is shown in Table 1 with details of the triage criteria and corresponding colours, while Table 2 contains the 25 main categories of symptoms. According to the CBD protocol, the results of the patient's interview will be presented as an IDC; for example, patients will be triaged by considering each criterion of their symptoms and the result will show the main symptom code, a colour code and a triage criterion. A result of "12 red 1" represents a critical emergency patient with cardiac arrest so that the emergency staff can request emergency medical resources and operate based on the corresponding essential response.

Table 1 :The explanation of Initial Dispatch Codes (IDC)

Colors	**Triage Criteria**	**Essential Response**
Red	Critical emergency patients	Responsible to pateint with Basic Life Support Unit: (BLS) <u>within 4 mins</u> after accident then responsible to pateint with Advance Life Support unit (ALS) <u>within 8 mins</u> after accident.
Yellow	Urgent emergency patients	Responsible to pateint with BLS <u>within 8 mins</u> after accident then responsible to pateint with First Response Unit (FR) <u>within 15 mins</u> after accident
Green	Not urgent emergency patients	Responsible to pateint with BLS <u>within 8 mins</u> after accident.
White	General patients	Responsible to pateint via telephone referral program and consider to BLS
Black	Not patients	No responsible to pateint

Table 2: The 25 main of symptom categories

Code	Symptom	Code	symptom
1	Abdominal/Back/Groin Pain	14	O.D./Poisoning
2	Anaphylaxis/Allergic Reaction	15	Pregnancy/Childbirth/Gyn.
3	Infectious Disease	16	Seizures
4	Bleeding (Non-traumatic)	17	Sick (Unknown)/Other
5	Breathing Difficulty	18	Stroke (CVA)
6	Cardiac Arrest	19	Unconscious/Unresponsive/ Syncope
7	Chest Pain/Discomfort/Heart Problems	20	Pediatric Emergencies
8	Choking	21	Assault/Trauma
9	Diabetic	22	Burns - Thermal/Electrical/Chemical
10	Environmental/Toxic Exposure	23	Drowning/Near Drowning/Diving or Water-related Injury
11	--Not define symptom--	24	Falls/Accidents/Pain
12	Head/Neck	25	Motor Vehicle Accident (MVA)
13	Mental/Emotional/Psychological	-	-

2. Method

2.1 Software development process

A medical mobile application based on CBD was developed for patient triage in Thailand to resolve the aforementioned problems associated with the pre-hospital process. The adapted waterfall methodology software was applied as a 7-step guideline for the development process [35-36].

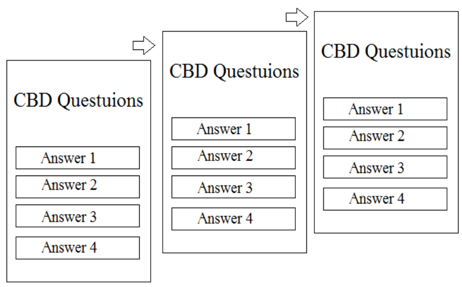
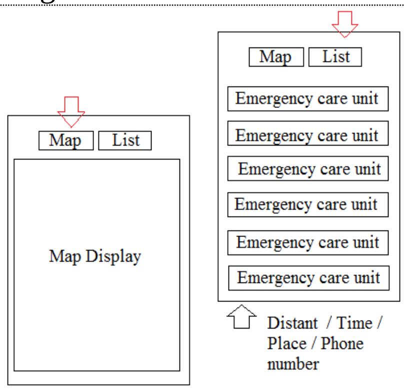
Step 1 Software requirement: This step involved collecting information from emergency doctors, emergency staff and nurses in order to identify the functions necessary to triage patients.

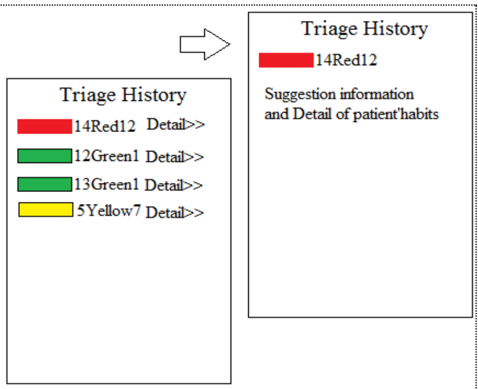
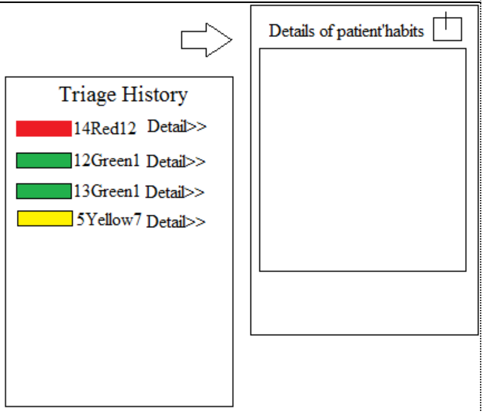
Step 2 Analysis: The development process involved considering the usability of the proposed application in terms of functionality, convenience, triage accuracy and accessibility. Functional requirements were identified based on the software requirement in step 1. The proposed benefits of using the application are shown in Table 3.

Step 3 Design: This step involved using the analytical results to design the functions of the application and the graphic user interface. The functions were designed by considering the practical use of the application. State diagrams were used to describe the system's behaviour. The functional design shown in

Figure 1 corresponds to the functional and graphical design in Table 3. In this step, the application was designed based on the requirements of a user interface on a mobile application, which included navigation components, input controls, screen proportion design, menu list navigation and a deep layout of the screen using the human-centred theory, Eight Golden Rules of interface design and Nielsen's Ten Heuristics [37-38].

Table 3. Functionalities of the Triage mobile application

Function	Propose	How to use	Benefits	Graphical design
1.Triage	To identify IDC	Interview patient or consider patient habit by following the questions of CBD in application question by question .The result will show IDC to requesting a pre-hospital resources .	IDC can scope an appropriate requesting to pre-hospital resources. The IDC together with part of suggestion where patient waiting in pre-hospital should be transferred .	 Point of design : 1.quickly accessible to triage 2.triage accuracy presentation 3.quickly accessible to a suggestion 4.direct manipulation for easy remembering 5.menu selection replace keyboard using
2.Finding responsibility of emergency care unit	To show nearby emergency care unit and a phone number	This function show emergency care unit based on Google map Application programming interface (API) with shortest transferring time consideration.	Patient or staff will have an information of emergency care unit which was ordered by transferring time from current location .	 Point of design : 1.quickly accessible 2.accessible timing 3.menu selection replace keyboard using 4.reduce short term memory load

3.Patient triage log file	To check the triage information	Patient or staff can find the previous information of IDC code to identify the requesting of pre-hospital process	Log file can provide triage information to inform the pre-hospital process and confirm triage information .	 Point of design : 1.practical used 2.design dialog yield closure 3.simplicity 4.adequate presentation of information
4 .Exporting IDC information	To send the information of IDC to associate emergency person	Patient or staff can send doctor or provincial emergency care unit a result of IDC which contains the detail of patients ,habits from the questions of CBD.	Provincial emergency care unit can use that information for preparing emergency resources when patient is transferring .	 Point of design : 1.practical use 2.convenience 3.simplicity 4.adequate presentation of information

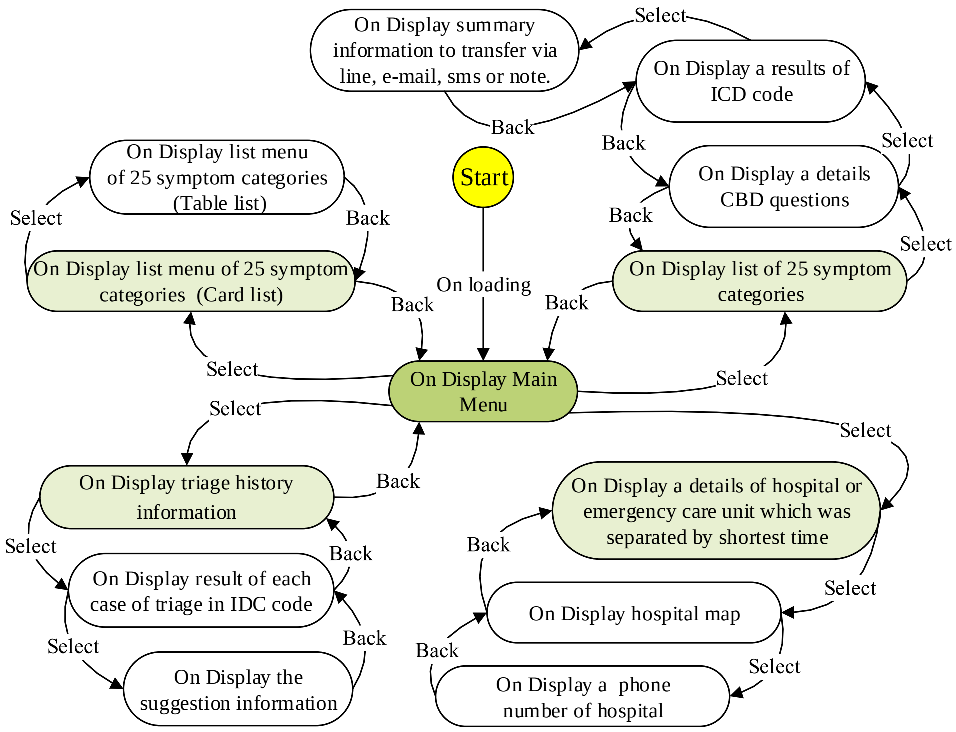


Figure 1 :State diagram shows the functional design of application which is corresponding to functional and graphical design based on the user requirement in Table 3.

Step 4 Development: This step involved applying the Ionic Framework, which is a non-native language for mobile application development. This framework is suitable for both iOS and Android operating systems. Firebase was employed for the user database, which included triage results and user information, as well as the other information used in the application.

Step 5 Testing: The advanced functions of a smartphone device that indicate its usability are its capacity to adapt (especially in medication mobile applications), users' interaction, perception of places and objects and the interaction between the system and users, especially in cases of emergency cases. Misplacing any of these elements would result in miscommunication, which would require more operating time. Hence, in this step, the application had to be tested by triage staff to determine its performance in terms of time. Moreover, the IDC accuracy and question flow of triage had to be tested and compared to the flow of the CBC protocol by emergency voluntary staff. Therefore, the three points on which the application was tested are illustrated in Table 4.

Table 4 : Points of consideration for the application testing

Testing Criteria	Proposes	Methods
1. CBD questions flow assessment	-Correct or incorrect IDC in each symptom	- 25 symptoms were tested and compared with step by step of CBD question -Testing by comparing with CBD handbook case by case which checked by medical emergency doctor
2 .Triage time evaluation	-Time of testing for using application, open handbook and emergency medical staff.	-Testing by comparing with simulated scenario and comparison time for using application, open handbook and emergency medical staff - Using independent sample t-test analysis to compare triage time consuming between application and staff experiences
3 .Application usability test	-Consider as user friendly and practical uses in real operation	-Evaluating by 10 emergency staffs who were selected as a sample group .Application testing and questionnaire were used . -Nielsen's ten usability heuristics mixed with the human-centered theory, and Eight Golden Rules of interface design were used for testing for application performance in term of usability and user friendliness.

Step 6 Operations: This step was taken after the verification of the ability of the application to produce an accurate CBD based on an accurate IDC by medical emergency doctors. Ethical approval for the application was requested before releasing the data to rescue teams, rescuers, community hospitals and emergency medical volunteers via Google Play and the App Store.

2. Results

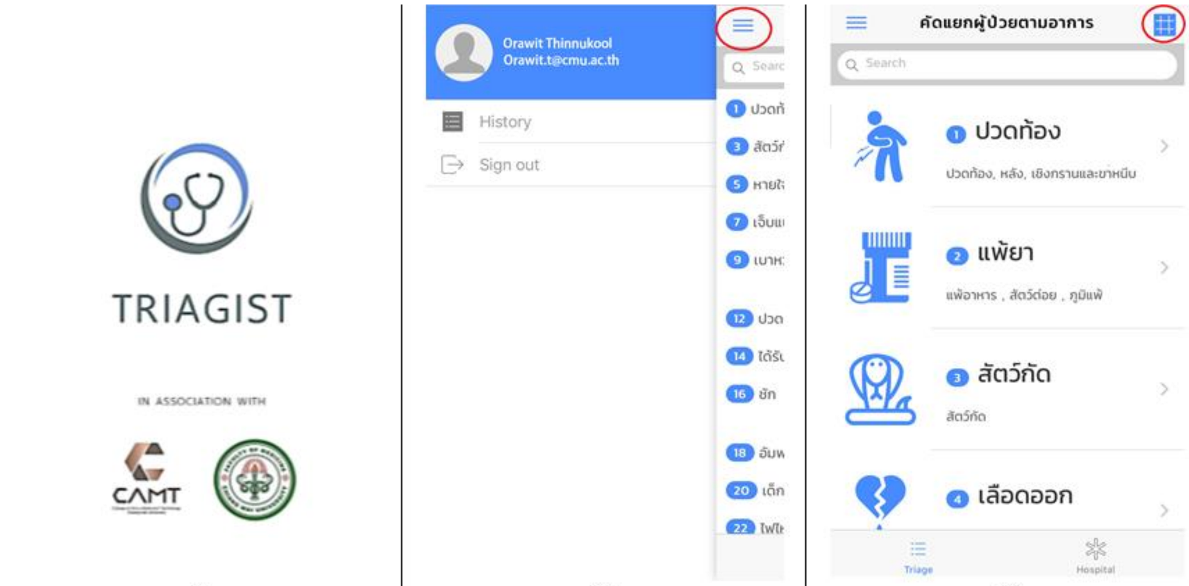
3.1 Development of Mobile Application

The application was developed using the Ionic Framework and evaluated based on compatibility, errors, missing information and quality. The final version that was released consisted of four main functions, including triage, finding the responsible emergency care unit, patient triage log file, and export IDC information.

The functions of the application were tested using iPhone 6s and Huawei Android phone (P20Pro). At the time of the study, smartphone specifications were defined for medium- and large-screen display devices, due to visibility concerns [39].

The application procedure starts when the user opens the application, and screen A in Figure 2 appears, showing the title and welcome graphics. The main menu screen is then displayed. The buttons on screen B support the application login and triage history. Screen L contains icons for the 25 symptom symbols for triage which are demonstrated in a table view (screen D) and list view (screen C), respectively.

As shown in Figure 2, on screens E-G, users can search by typing the symptom name or keyword(s) into the textbox and select a symptom from the list of search results. The steps for the CBD questions are shown on screen F. Users have to select their answer to go to the next question, and then continue until the IDC is displayed on screen H or I. Screen I shows the triage screening result, which identifies the IDC code and emergency status. The screen colour will be the same as the IDC code pattern. Suppose the IDC pattern is displayed in the form of “X colour Y”, the first X refers to the group number of the symptoms corresponding to the information input in Table 2 and the last Y refers to the level of urgency (1 being the highest and 9 being the lowest). On screen K, users are advised of some actions they can take while waiting for the emergency services. Moreover, they can record the IDC code via the application to summarise their condition, as well as the level of urgency. This will enable the emergency doctors/staff to gather information for the pre-hospital process. Additionally, on screen J, the application supports the export of the details of patients/emergency cases in a .pdf format to other applications, such as Line and Short Message Service (SMS). On screen M, users are able to find their nearest emergency care unit and hospital, as well as the contact information (phone numbers as shown on screen N). This data is sorted by the shortest distance and shortest time to the destination. Furthermore, a map with directions to hospital locations is provided on screen O with an overview of the information.

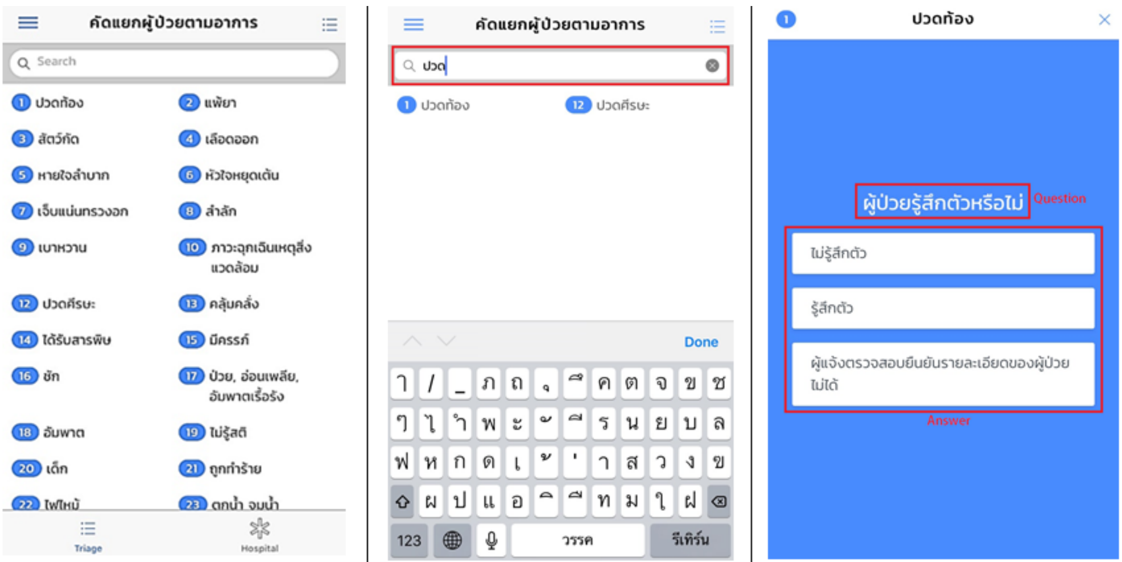


A B C

A: Main page of Application

B: The main menu which provide menu list adjustment of conveniences in real operation.

C: Menu in list view which present icon in each patient condition



D E F

D. Menu in table view which presents icons for patient conditions

E. User can search for triage types by typing a patient condition.

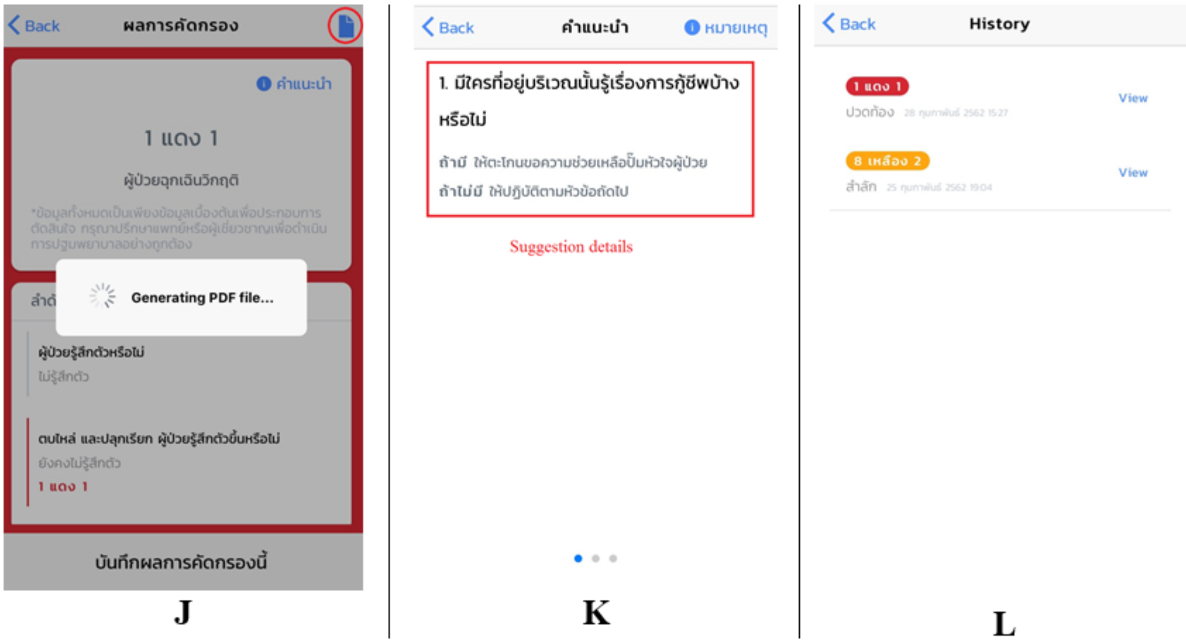
F. Screen shot showing a question to ask patient condition and a list of answers.

G H I

G: Screen shot showing the next question to ask patient condition and a list of answers. If a user is unsure about patient conditions, the user can step back to the previous questions to reconsider them.

H: The triage result screen showing an IDC code (Yellow) to present the level of emergency index and the answer summary of the CBD questions.

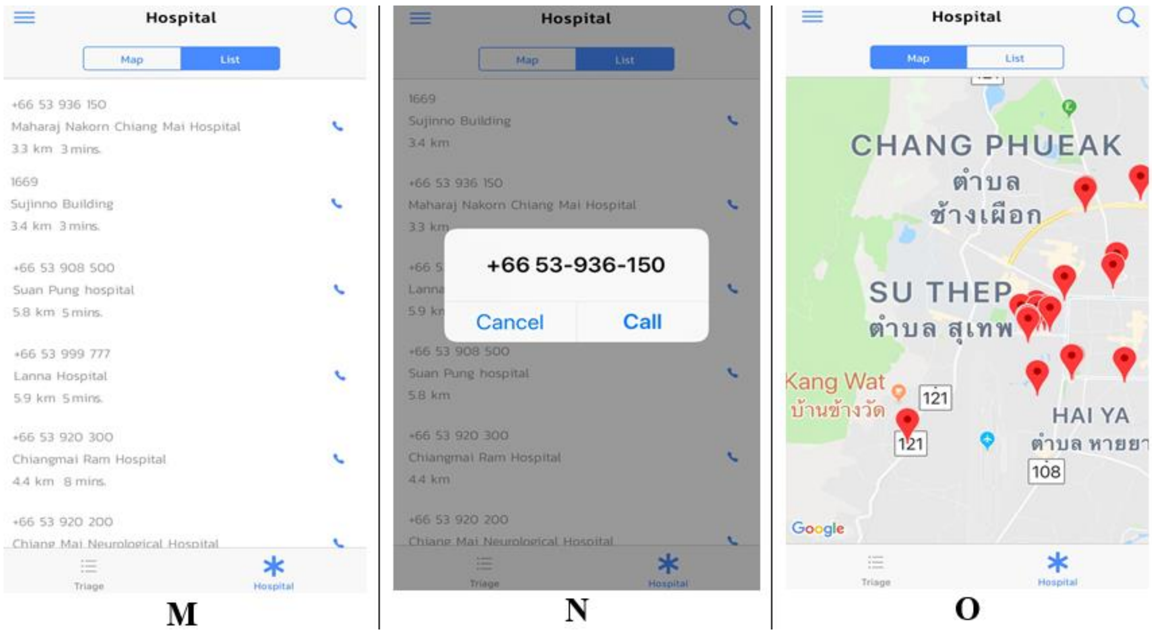
I: Screen shot showing a triage result with the suggestion button, where the user can get more information for first aid treatment or any further suggestions for the pre-hospital process including the button to record the triage result.



J: Screen shot of building a pdf. file of IDC result to send to a medical unit

K: A suggestion screen shot and the suggestion details

L: log file of triage for history information



M: Screen shot showing a list of nearby hospitals or any medical institutions (ascending sorted by the distance from the current location)

N. Phone numbers are linked and enabled for click to call to initiate immediate phone calls from the application.

O. Screen shot showing a map with nearby hospitals or any medical institutions.

Figure 2: Graphic user interface of Triagist mobile application

2.2 CBD question flow assessment

The CBD questions used in the application were tested by evaluating the accuracy of the IDC results. All the 25 symptoms were tested in each question by following the flow in the CBD handbook. Emergency medical doctors tested the application by simulating a scenario and the results were compared with the handbook. After verifying and approving the flow of the CBD questions, the testing proceeded to the next step.

2.3 Triage time evaluation

The application was used to triage patients in order to test its reliability and efficiency compared to various triage methodologies. 2 of the 25 symptoms, trauma and non-trauma, were tested in a simulated scenario and role-playing was used to communicate the patients' condition to the medical staff. The accuracy of the resulting IDC was evaluated and it was confirmed to be suitable for requesting resources. This involved comparing the IDC and the triage time spent by the emergency staff in obtaining it using the above-mentioned process based on three different methods: 1) using the application, 2) following the CBD protocol from the handbook, and 3) relying on emergency medical staff's experience. Four emergency medical staff participated in the pilot test.

The results of testing each method in each scenario are shown in Table 5. It is clear that using the application for triage was as fast as the time taken by experienced emergency staff and as accurate as following the CBD protocol from the handbook. Some IDC misrepresentations were found when performing triage by relying on the staff's experience.

Table 5:Scenario test comparison for triage time testing and triage result

Patient habits	Application	Open Handbook	Experienced staff
Scenario 1: **Environmental/Toxic Exposure** 1.conscious or breathing 2.unable to speak normally (work of breathing)	5 seconds IDC: 14 Red 2 Critical Patient	13 seconds IDC :14 Red 2 Critical Patient	4 seconds IDC :14 Red 1 Critical Patient
Scenario 2: **Environmental/Toxic Exposure** 1.conscious or breathing 2.no asthma 3.breathe fast 4 .age <20	8 seconds IDC :14 Red 2 Critical Patient	14 seconds IDC :14 Red 2 Critical Patient	6 seconds IDC :14 Red 2 Critical Patient
Scenario 3: **Anaphylaxis/Allergic Reaction** 1.conscious 2.breathing 3.speak normally 4.fainting 5.drug allergic	20 seconds IDC : 2 Yellow 4 Urgent Patient	28 seconds IDC : 2 Yellow 4 Urgent Patient	15 seconds IDC : 2 White 2 General Patient
Scenario 4: **Anaphylaxis/Allergic Reaction** 1.unconscious 2.responding to other 3.breathe fast 3.speak normally 4.asthma 5.age <20	15 seconds IDC : 2 Red 2 Critical Patient	18 seconds IDC : 2 Red 2 Critical Patient	10 seconds IDC : 2 Yellow 8 Urgent Patient

Another test was undertaken to confirm the triage time by comparing the results based on two methods, the first of which was using the application and the second was relying on the emergency staff's experience. Please note that the hand book was not used to evaluate the triage condition. It was only used to test the reliability of the application, since it is not a practical process for real-world operation.

The test conditions were established based on the acquisition of sample data from the twelve emergency medical staff, each of whom had no more than 5 years' work experience. The medical staff were split into two groups of six. Triage was performed by both of these groups using the application based on their experience. The test cases included 13 out of 20 scenarios, which covered the 25 main symptom categories (See Table 2). The average triage operational time was calculated.

The results of testing the triage time shown in Figure 3 indicate that the use of the application was more efficient to triage non-trauma cases than relying on experienced staff; on the other hand, experienced staff were more efficient than the application in triaging trauma cases.

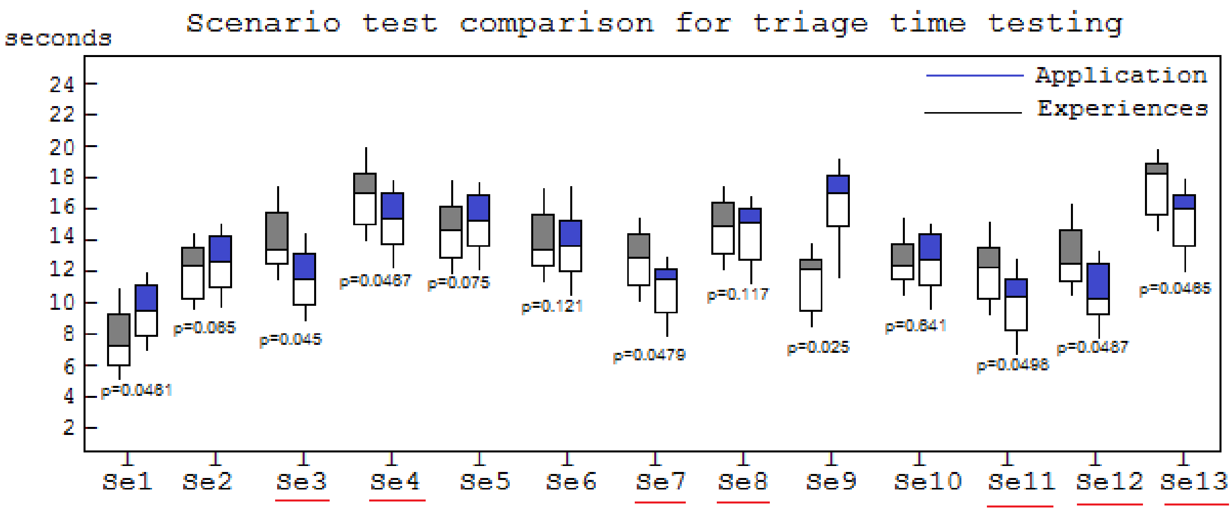


Figure 3 **:**Scenario test comparison for triage time testing and triage result from R program version 3.1.2 The red underlined scenario represented the trauma condition (emergency patient)

2.4 Application usability test

It was important to test the usability of the application to ensure its quality and reliability. The focus had been on developing a high-quality medical system based on reliable software in order to address the practical concerns that were the pain points of the previous system. Hence, the criteria of Jakob Nielsen's usability test technique were applied in certain scenarios. The key points tested were the occurrence of difficulties, the doubt of visual representation, doubt of usage, missing information and confusion when using the application. Each function of the application was tested by 12 emergency medical staff, including doctors and nurses. The results of the findings for each criterion (based on user motivation), as well as the application's functionality, are shown in Table 6.

The triage function was misunderstood in 12 instances (ranked 2nd in operational errors). Information was found to be missing when users wanted to repeat the CBD questions, which led to the duplication of the IDC of patients' conditions in the log file. Doubt of the visual representation was found when users did not read the information shown on the left-hand side of the previous answer and it was sometimes difficult to find the answers to previous CBD questions. The second function, finding an emergency care unit, was found to be missing 4 times and this was ranked the 3rd overall operational error. This may have been due to the use of third party navigation applications because the list of available emergency care providers' locations is displayed using navigation applications such as Google Maps. It is also possible that other errors arose from navigation applications. When testing the next function, the patient triage log file, doubt on its usage and misunderstanding were found in 3 cases. The logging file operated as a historical record of triage information to confirm the patient's condition. The last function tested was the data export function to export IDC information to other applications, such as SMS, Line, WeChat, e-mail, etc., and its use was found to be problematic in 3 cases. Users encountered problems in sending information when the device was not connected to the internet. The function was found to be confusing in 4 cases because the users assumed that it was meant to be used to produce a medical report.

Confusion was found to be in the 1st ranking of the evaluation of users' motivation based on a total of 13 cases. Doubt of usage, which occurred during the log file exportation of IDC information was ranked 2nd, while doubt of visual representation of some graphics and figures in the application during the triage function, finding the emergency care unit function, and the exporting of IDC information function were ranked 3rd, 4th and 5th respectively.

Table 6: Cross matrix usability test result

		User Motivation						
Function Test		Usability difficulties	Bug founding	Doubt visual representation	Doubt on usage	Missing information	Misunderstand	**Total**
	1 .Triage	1	0	3	2	0	6	12[2]
	2 .Finding responsibility of emergency care unit	2	0	2	0	4	1	8[3]
	3 .Patient triage log file	0	0	1	3	0	3	7
	4 .Exporting IDC information	3	0	2	3	0	4	13[1]
	Total	6	0	7[3]	8[2]	4	13[1]	22

3. Discussion

This research was conducted to respond to the question: What should a mobile medical application include to help primary care physicians or patients to screen symptoms in both normal and emergency conditions? This involved designing and developing an application that would enable patients in Thailand to determine their own symptoms and assess the need for emergency treatment.

The results were based on an application analysis and literature review from previous studies of several medical application systems [2], the emergency alert system, map positioning for emergency medical services, patient monitoring and tracking system for high-risk patients who require services from EMS [3-5][16][22][27-28] and dental application triage development [26], all of which are systems that can be used to support medical emergency operations. Hence, the proposed application was designed for the Thai social context and it may be used in the same way as other similar applications to provide patients with an alternative choice for emergency aid.

The application for patients' triage was developed by following the CBD to request an IDC for the pre-hospital process [32-34] and it can serve as a tool for primary emergency medical practitioners and general users. The adapted waterfall methodology was used together with the Ionic framework to produce a system that can be used on both Android and iOS operating systems

[35-36]. The human-centred theory, Eight Golden Rules of user interface design and Nielsen's Ten were employed to design an appropriate practical user interface for real emergency situations [37-38].

The 25 main symptom categories covered by the CBD were used to design and develop the application [32] and twelve emergency medical staff, including doctors and nurses, tested the following aspects of the system: triage protocol correction, triage reliability, usability and users' satisfaction.

Four functions were developed as a result of the proposed application: (1) the triage function to identify the IDC, (2) the finding of emergency care unit function, (3) the patient triage log file function providing triage information to support the pre-hospital process and confirm triage information, and (4) the exporting IDC information function for sending the obtained IDC to provincial emergency care units where it can be used to prepare emergency resources while the patient is being transferred.

The first application test was undertaken to check the reliability of the triage and the time spent performing triage under different conditions. This involved establishing a scenario to compare triage times. The results showed that using the application took less time than relying on experienced staff in the case of non-trauma patients, while using experienced staff to identify IDC in case of trauma patients took less time than using the application. The accuracy of identifying IDC using the handbook and the application was found to be similar.

The second test involved sampling 13 scenarios from a total of 20. In the case of trauma patients, the majority of experienced staff required less time to triage than the application, but the triage may have resulted in misrepresenting IDC. The application was shown to be useful in the majority of the scenarios in terms of operational time and reliability, but it is more likely to be suitable for use with non-trauma patients. However, Savamongkornkul found in his study that the performance of mobile applications in triage could be enhanced when they were used by experienced staff [13].

The second test was conducted as described in section 3.4, the application usability test. The testing criteria applied were the human-centred theory, Eight Golden Rules and Nielsen's Ten Heuristics [37-38]. The results showed that the application still had the weakness of some confusion in its use.

The triage function, in which users needed to answer a number of CBD questions, was ranked the highest weak point, since some users misunderstood the number of answers required. In fact, some questions only required 1 or 2 answers.

It was also found that missing information from the finding emergency care unit function was caused by the Google API providing incorrect locations that are not emergency care units. Hence, the API usage needed to be amended in order to find the correct locations.

The testing of the application highlighted some remaining weak points based on users' perception, but it was proved to be useful overall for patients to self-assess their symptoms correctly, including emergency situations, which will increase the effectiveness of treatment. Therefore, this project can improve the development of primary care based on designing an application that can provide medical professionals with more knowledge at the pre-hospital stage. The utility of the research can improve the performance of primary medical emergency staff based on the accuracy of the triage standard. The overcrowding of hospital centres in each Northern Province can be reduced when patients apply the triage mobile application for a primary diagnosis. As mentioned earlier, the results concomitantly support those of Savamongkornkul [13]. Also, if patients use the application as a tool to triage themselves when they experience a suspicious symptom, it can help the ED to reduce the service time and increase the quality of medical service and Kazi [11] observes that service time is related to patient outcome. Hence, this application is very suitable for patients who request CBD codes without comprehensive medical knowledge and skills.

4. Conclusion

A new system was proposed and developed to respond to the problems with the system used by the National Institute of Emergency Medicine of Thailand. The Thai mobile medical application for patient triage based on the CBD was the first mobile application for triage in Thailand to support the pre-hospital process, especially for patient triage using IDC to request emergency resources. The application was designed and developed based on usability and reliability tests, which is considered to be appropriate for the Thai social context. These tests confirmed that the application is useful in terms of operational time and reliability, although it is more likely to be suitable for non-trauma rather than trauma patients. Hence, the application can be used as a practical tool as well as an educational tool for new emergency staff who lack sufficient skills in the medical emergency field.

In summary, the Thailand mobile medical application for patient triage is smart technology, which can benefit users as a tool for rapid triage screening, educate patients and new emergency staff, and prevent the overcrowding of emergency care units in Thai hospitals.

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Research output: Part 2 Patient Triage System Development for Supporting the Operation of Dispatch Centres and Rescue Teams

1. Background

Mobile healthcare applications have been applied in many medical settings, especially in this era of digital technology (Malone et al., 2020) and an increasing number of people are using smart technology to access primary healthcare via a smart phone (Verzantvoort et al., 2018; Malone et al., 2020). The advance of smart technology has led to it being widely used for healthcare purposes, for example, monitoring patients (Goodwin et al., 2016; Li et al., 2019), tracking patients (Majumder and Deen, 2019), expert or doctor consultation (Hasselberg et al., 2017; Carter et al., 2019; Alam et al., 2019), healthcare medication and diagnosis (Kanakasabapathy et al., 2017), and health education (Sousa & Turrini, 2019). Primary care (41%) and prevention (47%) have been reported to be the most common healthcare services provided via a mobile application (Malone, N. C, el al., 2020).

Healthcare applications based on smart technology are extremely popular in several countries in emergency medical settings. Many systems have been developed to enable first responders or emergency staff to make a rapid assessment in order to triage patients at each stage of healthcare management (Bellini, 2013; Christopher et al., 2019; Westphal et al., 2020; Sutham et al., 2020) because triage is the key to effective management in emergency medicine (Vassallo et al., 2017). The triage in healthcare management can be classified into three stages, namely, pre-hospital triage (stage 1) which involves dispatching an ambulance and pre-hospital care resources, triage at the scene (stage 2) by first response emergency staff who are attending the patient and, triage on arrival at the hospital or emergency unit (stage 3) (Robertson-Steel, 2006). Several smart systems have been widely used to reduce the time consumed in the triage process by supporting rapid decision-making (Boltin et al., 2018) and self-triage (Mir, 2018).

The Anglo-American Model (AAM) combined with the Criteria Based Dispatch (CBD), which is focused on the pre-hospital process, has been used for Thailand’s emergency system (Coster et al., 2018), and several systems have been designed and developed by the National Institute for Emergency Medicine of Thailand (NIEM) to support the country’s emergency medical services. According to a report from the Thailand Academic Conference on Emergency Medicine in 2019, the next generation of Thai EMS must be based on a digital platform to support the emergency services (National Institute for Emergency Medicine, 2019).

However, the main problem with developing healthcare applications based on smart technology in Thailand is the lack of an information technology infrastructure compared to other countries (Towse et al., 2004; Suttisak, 2015; Pagaiya et al., 2019); for instance, the NIEM developed an associated system to triage patients, but it did not work in practice. Therefore, every Thai medical institution has been encouraged to develop smart technology to resolve this current problem.

1.1 Prior work

Sutham and his team recently developed a Thai mobile application to triage patients in support of Thailand Science Research and Innovation (TSRI). They used the emergency Severity Index (ESI) as standard of classification in the application. This system was suitable for rescue teams, community hospitals and emergency medical volunteers to triage patients (Sutham et al., 2020).

When this application was implemented, it was found that it could identify the Initial Dispatch Code (IDC), which leads to the allocation of emergency resources. When a patient makes a phone call to a dispatch centre or local emergency centre, the IDC can identify the level of urgency and medical resources needed, while simultaneously sending information about the patient’s condition to the dispatch centre via an email, SMS or Line application.

However, the pilot test highlighted some weak points that needed to be addressed; for instance, the application did not completely connect to the dispatch centre, it did not respond to the geolocation data, the triage results were not recorded in an appropriate format and it was hard to recheck information about emergency cases.

Therefore, in order to enhance the performance of dispatch centres or rescue team centres in managing emergencies using ordinary channels such as emergency phone calls and the Triagist mobile application, it is necessary to determine the ability of the previous version to effectively manage the first stage of emergency medicine by considering its functions. Hence, the purpose of this research is to develop a new system to support the connection of dispatch centres or operational centres to the Triagist mobile application. This system will be web-based and have the ability to recheck the results of the IDC and identify the geolocation of services by referring to several current researchers, who have also developed a new system (Jansen et. al., 2015; Weinlich et al., 2018; Costa et al., 2019).

1.2 Triage Systems

Triage systems are widely used in emergency medicine. Some of them are applied via a computer, rather than a triage medical manual. There are no exact characteristics for each type of triage system. Their characteristics and usage are different from country to country and region to region. Jafar et al. (2019) divide triage systems three types, namely primary, secondary, and hospital triage. Numbers and colours are normally used to represent the level of urgency, sickness level, patient ability and resource allocation. An explanation of each type is provided in Table 1.

Table 1: Triage System

Type	Characteristics
Primary triage	This type of system is based on considering the patient's condition. Patients are prioritised for treatment according to their ability to respond in the primary stage, indicated by a particular colour)Bhalla, 2015; Pollaris and Sabbe 2016; Hodgetts et al, 1998; Coule and Horner., 2007; Garner et al., 2001(
Secondary triage	This type of system is used to diagnose patients who made need to continue using the existing care services. Patients are marked by a colour to identify the likelihood that they will survive. Secondary triage is used after the patient has been diagnosed and given primary treatment by medical staff.)Koenig and Schultz, 2010; Smith, 2012(.
Hospital triage	This system is used to determine the validity and reliability of the condition of emergency patients in emergency units in hospitals in order to allocate the care to those who need it most.)Wuerz et al., 2000; Wuerz et al., 2001; Eitel et al., 2003(

1.3 Implementation of Related Emergency Systems

Several researchers have developed triage systems that contain the necessary criteria to classify patients' condition. Some of the associated research and development that refers to emergency medicine is detailed below.

Sutham et al. (2020) recently researched and developed a triage medical application called Triagist, which can be used to classify the level of emergency based on an initial dispatch code (IDC). The Triagist can be used as a practical tool, as well as an educational one for new emergency staff who lack comprehensive emergency medical knowledge and skills. This computerised triage system corresponds to the primary stage of emergency medicine.

Sumrumeram (2018) developed a medical application that can track high-risk stroke and stemi patients who require time-sensitive Emergency Medical Services (EMS). This application is based on smartphone technology and the use of a Global Positioning System (GPS) to track patients and classify their status. The system can accurately pinpoint patients' location. This study is of great benefit to both the emergency medical services and patients by optimising the survival rate. This computerised triage system corresponds to the primary stage of emergency medicine.

Michael et al. (2018) applied the geolocation from a smartphone to enable emergency medical services (EMS) to quickly respond to emergency calls. Having tested the accuracy of GPS, Wi-Fi (wireless LAN network) and LBS (location-based system) in eleven different countries, the combination of Wi-Fi geolocation and GPS was found to accurately identify emergency locations, especially within or close to buildings.

Corey et al. (2016) developed a triage system for dental emergencies. This system can identify tooth symbols based on intraoral images, which helps dentists to assess the condition of a tooth. Moreover, users can self-identify the condition of the tooth before requesting the dental services. This system is an example of the primary stage of emergency medicine.

Romano et al. (2016) used smart technology in the form of a mobile phone to support emergency responders. The geolocation and necessary information, such as photos or videos, are delivered to the operation centre. This is a practical system that enables a faster response to be made. This research demonstrates the ability of the geolocation to help EMS to locate the patient prior to the pre-hospital process.

Lee et al. (2016) researched and developed a smartphone application that burn injury patients can use for consultation in an emergency. This application enables users to indicate the specific injured bodily surface(s) and calculate the total bodily surface area affected by the burn and automatically send a text message to the experts, who can quickly respond and help patients to triage themselves prior to the pre-hospital process. This system is an example of basic triage at the primary stage of emergency medicine.

1.4 Thai Triage Standard

The AAM is used by the emergency services in Thailand with a focus on supporting the pre-hospital process. The Criteria-Based Dispatch (CBD) protocol is also used to identify patients. This method involves the use of five colour codes to rapidly identify the condition of patients who are requesting hospital treatment before admitting them to the hospital. Table 2 shows the classification of IDC and explanation of each IDC essential response. Moreover, the NIEM summarises symptoms into 25 main categories (National Institute for Emergency Medicine, 2011; Gilboy et al., 2012), as shown in Table 3.

Table 2: Explanation of Initial Dispatch Codes (IDCs)

Colour	Triage Criteria	Essential Response
Red	Critical emergency patients	Basic Life Support Unit: (BLS) responds to the patient within 4 minutes of the accident and the Advanced Life Support unit (ALS) responds within 8 minutes of the accident.
Yellow	Urgent emergency patients	The BLS responds to the patient within 8 minutes of the accident and the First Response Unit (FR) responds within 15 minutes of the accident.
Green	Not urgent emergency patients	The BLS responds to the patient within 8 minutes of the accident.
White	General patients	Respond to patient via telephone referral programme and consider BLS
Black	Not patients	No response needed.

Table 3: 25 main symptoms from the National Institute for Emergency

Code	Symptom/Condition	Code	Symptom/Condition
1	Abdominal/Back/Groin Pain	14	O.D./Poisoning
2	Anaphylaxis/Allergic Reaction	15	Pregnancy/Childbirth/Gyn.
3	Infectious Disease	16	Seizures
4	Bleeding (Non-traumatic)	17	Sick (Unknown)/Other
5	Breathing Difficulty	18	Stroke (CVA)
6	Cardiac Arrest	19	Unconscious/Unresponsive/ Syncope
7	Chest Pain/Discomfort/Heart Problems	20	Pediatric Emergencies
8	Choking	21	Assault/Trauma
9	Diabetic	22	Burns - Thermal/Electrical/Chemical
10	Environmental/Toxic Exposure	23	Drowning/Near Drowning/Diving or Water-related Injury
11	Undefined symptoms	24	Falls/Accidents/Pain
12	Head/Neck	25	Motor Vehicle Accident (MVA)
13	Mental/Emotional/Psychological	-	-

2. Method

2.1 System Usability Test

Usability testing is a critical process for the success of novel smart health technology. There are many ways to conduct a usability test, one of which is to collect feedback from the target users with a usability questionnaire (Lewis, 1995; Lund, 2001). Lewis (2002) proposed the issue of an after-scenario questionnaire as a critical test based on the same target users who identified the system requirements. Hence, this step is required to ensure the quality and reliability of the back-end and front-end design of the system. In this study, the participants were asked to complete a questionnaire at the end of the scenario trial, but the rating scales of the evaluation were redesigned to contain 5 scales rather than the 7 in the after-scenario questionnaire. The usability test criteria and descriptions are shown in Table 4.

Table 4 Usability test criteria (Lewis, 2002)

Points to consider
1. This system was easy to use
2. I could effectively complete tasks and scenarios using this system.
3. I could complete tasks and scenarios quickly using this system.
4. It was easy to learn to use this system.
5. It was easy to find the information I needed.
6. The information provided in the system was easy to understand.
7. This system has a pleasant interface.
8. This system has the functions and capabilities I expected it to have.

2.2 Software development platform

Laravel, which is a highly-regarded software platform that is currently used to design most PHP frameworks (Yadav et al., 2019; Majida et al., 2019) due to its provision of strong configuration and high technical standard, was chosen to develop the system for the dispatch centres or rescue team centres. This platform also supports the use of a universal extendable dashboard, inspector, reusable components, authentication, authorisation, and the integration of tools for making web applications faster (Akshay, 2019).

2.3 Sample to Assess the System

The sample consisted of 68 volunteers (n=68) from active members of rescue teams in Chiang Mai and Lampang, as well as emergency medical staff. They were recruited using a purposive sampling technique. The samples were classified into three groups of rescue teams, volunteers, and emergency medical staff based on at least two years of emergency operation experience. Each group was divided into five sub-groups depending on their experience of emergency operation and their demographics are shown in Table 5.

Table 5. Demographics of samples (n=68)

Points	Characteristics	Percentage	(n)
Gender	Male	73.53	50
	Female	26.47	18
Experience	A: 2-3 Years	39.71	27
	B:3-4 Years	32.35	22
	C:5-6 Years	11.76	8
	D:7-8 Years	11.76	8
	E:9-10 Years	4.41	3
Emergency type	Rescue teams	55.88	38
	Volunteers	26.47	18
	Emergency Medical Staff	17.65	12

2.4 Assessment Protocol

Having established a scenario by which to test the system, a system manual, username and password to log into the system were sent to the participants via email. They were asked to complete the tasks by 1) Logging into system the using a tablet or personal computer; 2) Finding the IDC results from any report; 3) Finding the patient's condition; 4) Understanding the patient's condition; 5) Identifying the geolocation and approving it from the Triagist mobile application; and 6) Approving the IDC case. Three IDCs were randomly generated for each person. When they had concluded the allotted tasks, the participants were required to complete an online questionnaire to collect their feedback to evaluate users' satisfaction with the system.

2.5 Software development process

The development of the software for the dispatch centres or rescue team centres was designed to solve the problems associated with the pre-hospital process. Design thinking was used as a methodology to develop a functional system by understanding users, challenging assumptions, redefining problems and creating innovative solutions to test a prototype (Gerd Waloszek, 2012;

Interactive Design Foundation, 2018). This method consists of the 5 stages detailed below.

Stage 1: This stage involved an analysis of information collected from emergency doctors, dispatch centre staff and rescue teams to determine the system requirements, such as the functions necessary for dispatch centre or rescue teams to triage patients. The human-centred theory was used to analyse users' requirements.

Stage 2: In this stage, the factors necessary for developing the web-based system in terms of functionality, convenience and accessibility were considered and the back-end functional requirements were identified based on the software requirements from the previous stage.

Stage 3: The functions, graphical user interface and system architecture were designed in this stage. The functions were designed based on considering the practical use in a real operation by contacting users via a phone call together with the Triagist application. Moreover, the system was designed based on the requirements of the user interface. The components of the front-end system design included a menu list, geolocation graphic, navigation and input controls. The Eight Golden Rules of interface design and Nielsen's Ten Heuristics were used to design an appropriate graphical interface (Nielsen, 1994; Cooley, 1989).

Stage 4: The prototype was generated by the Laravel programme **(**Yadav et al**.**, 2019**)** using the findings from the earlier stages to obtain the best possible functionality to support the provincial dispatch centres. This framework was suitable for modification to connect the Triagist application and the patient triage system. The triage information obtained from the application is recorded onto the web-based system in the Firebase.

Stage 5: this was the final stage, which included testing the system based on a usability test to ensure the quality and reliability of the back-end and front-end design. The preliminary application was tested by 68 active members of rescue teams in Chiang Mai and Lampang, as well as emergency medical staff, having been provided with an indirect link to download the application. The usability of the questionnaire was evaluated after the scenario tasks had been completed. However, the rating scales for the usability test in this study were redesigned to contain five scales rather than the seven scales in the original after-scenario questionnaire. Subsequently, the results were evaluated as a fixed point. After the Triagist application had been validated, it was incorporated with the patient triage system for implementation.

2.6 System Architecture

The system in Figure 1 represents the overall system in this study which consists of a combination of the current Triagist application and a patient triage system to support dispatch centres or rescue teams**.** The Triagist application provides IDC results to indicate patients' status, while the patient triage system can retrieve the IDC results with a list of each patient's conditions, geolocation, and the date and time**.** In cases of emergency, emergency officers can assess the IDC results of users in real-time from the application**.** In critical cases, they can directly call the patient to determine the situation and then request emergency resources, such as an ambulance, medical staff or rescue teams to handle the emergency in a timely manner. Moreover, the patient triage system can also give medical doctors information about patients' condition before they arrive at the hospital; hence, it supports three hospital triage systems in healthcare management.

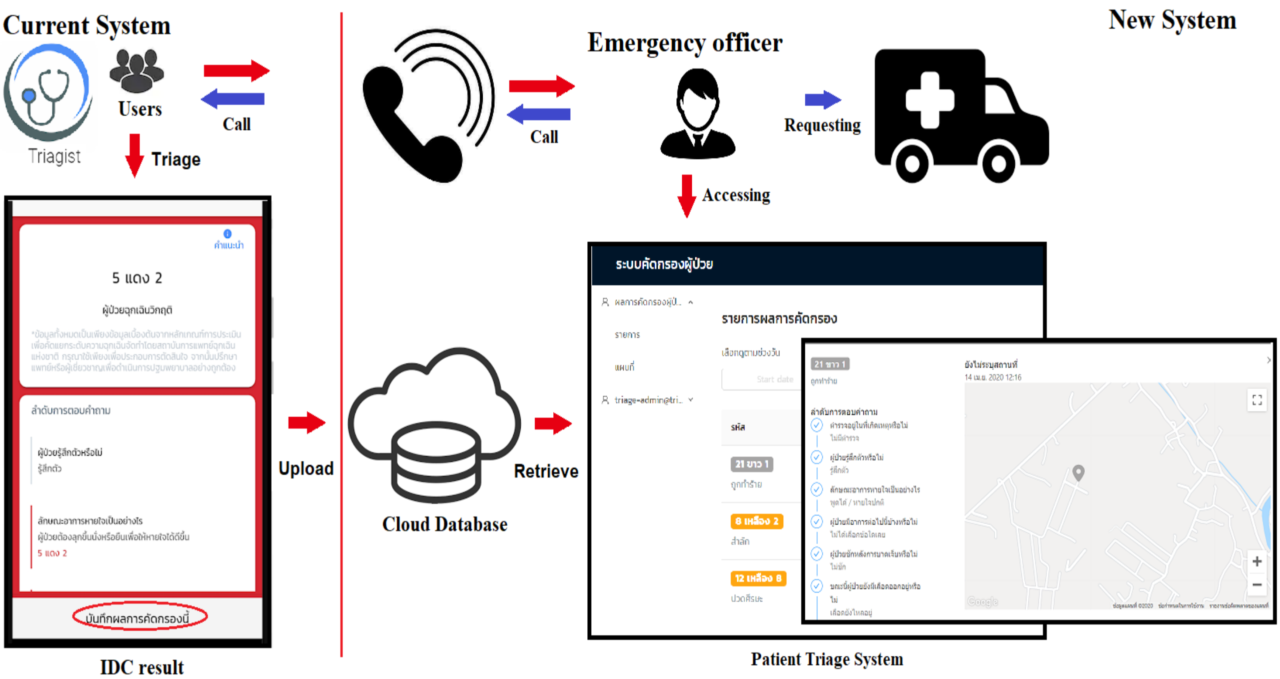
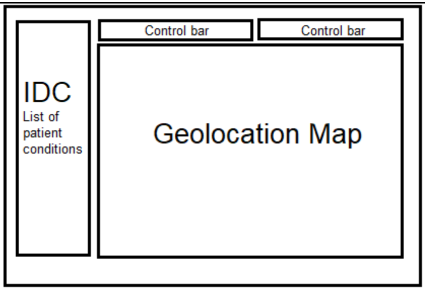
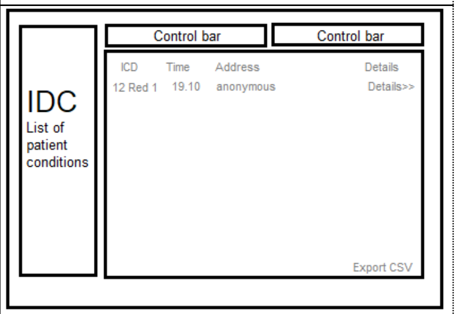


Figure 1: Overview of the patient triage system for dispatch centres or rescue teams. Note that the blue arrow indicates the future operation after the Triagist application is accepted as operating with the current Thai EMS.

2.7 System Development Analysis and Design

The current patient triage system, which was designed to support emergency dispatch centres or rescue teams, was analysed to design the necessary functions and graphical user interface for the development of the system. The results of the analysis of the functionalities of the system are shown in Table 6.

Table 6. Functionalities of the patient triage system for provincial dispatch centres

Function	Propose	Points to design	Benefits	Graphical design
1. IDC geolocation map	- To locate the IDC of each patient who submits the IDC results. - To identify the location of an anonymous user.	- Response to geolocation and patient conditions information. - Support the current emergency operation tasks.	- Staff can request the appropriate pre-hospital resources. - Easy to access address of both anonymous and enrolled patients.	 Points of design : 1. Quick accessibility to IDC geolocation and patient information. 2. Direct manipulation for easy remembrance. 3. Minimalist design, clean and clear.
2. IDC management	- To sort a number of cases of IDC by time period and type. - To report emergency cases by exporting to a CSV file.	- Response to list of IDC and patient information. - IDC information has to be exported in a type of file that is supported by the programme used by administrators.	- Staff can assess each IDC to approve or recheck the triage information. - Support for administration tasks such as a hospital cost assessment.	 Points of design : 1. Quick accessibility to a list of IDC information. 2. Sorting command must be clear and simple. 3. Minimalist design, clean and clear.

3. Results

3.1 Patient Triage System Interface Development

User authentication was the first consideration when developing the back-end system. A simple web-based application was designed for the back-end management services. The user's authentication provides each dispatch centre or rescue team with permission to access the system. A screenshot of the login authentication is shown in Figure 2.

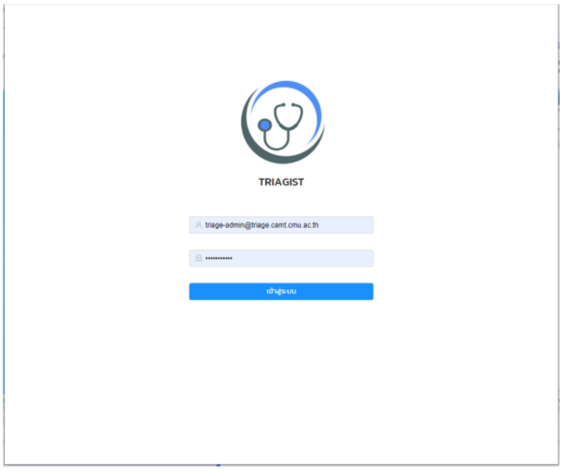


Figure 2: Screenshot of login authentication

The geolocation of the triage medical system was then developed. The geolocation together with the patient's condition enabled the situation to be evaluated based on the level of emergency. The IDC results illustrated in the geolocation map are shown in Figure 3. Each coloured points on the map represent the levels of IDC according to Table 2 (Sutham et al., 2020). Moreover, these results can be classified by start date to end date and by patients' symptoms covering the 25 symptom categories of Sutham et al. (2020).

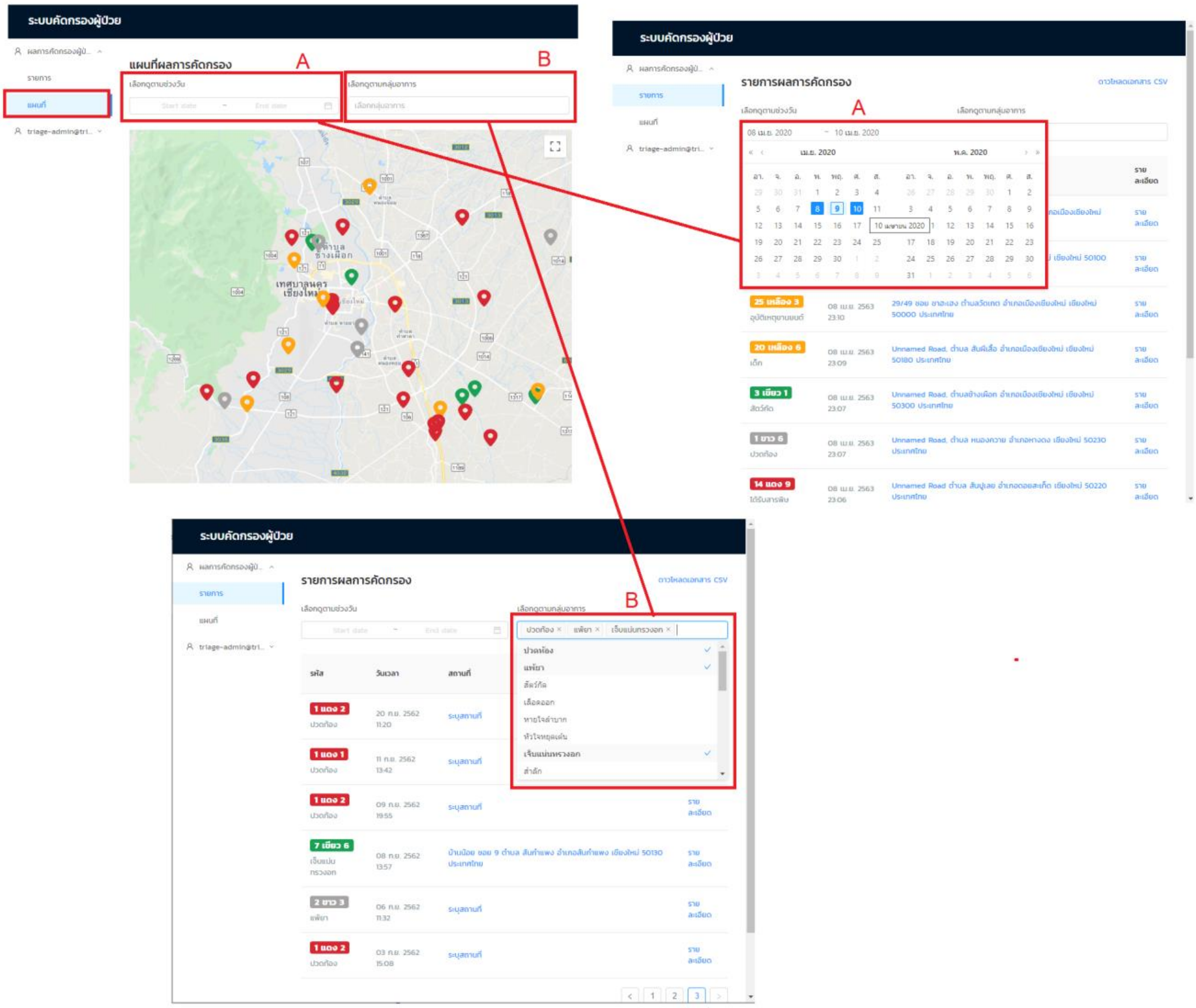


Figure 3: Screenshot of the triage geolocation map. The IDC results classified by start date and end date are shown in rectangle A and by patients' symptoms in rectangle B.

The screenshot in Figure 4 shows the list of IDC results retrieved from the Triagist users. Rectangle C displays the sequence listing of case submissions with the IDC level, date and time, and location. Rectangle D displays the individual cases in terms of the patient's habits following the CBD questions in the application. Meanwhile, the patient's location is shown as a detailed location and geolocation map (rectangle E). The Triagist application will be monitored by the staff who operate the system in the event of any missing geolocations.

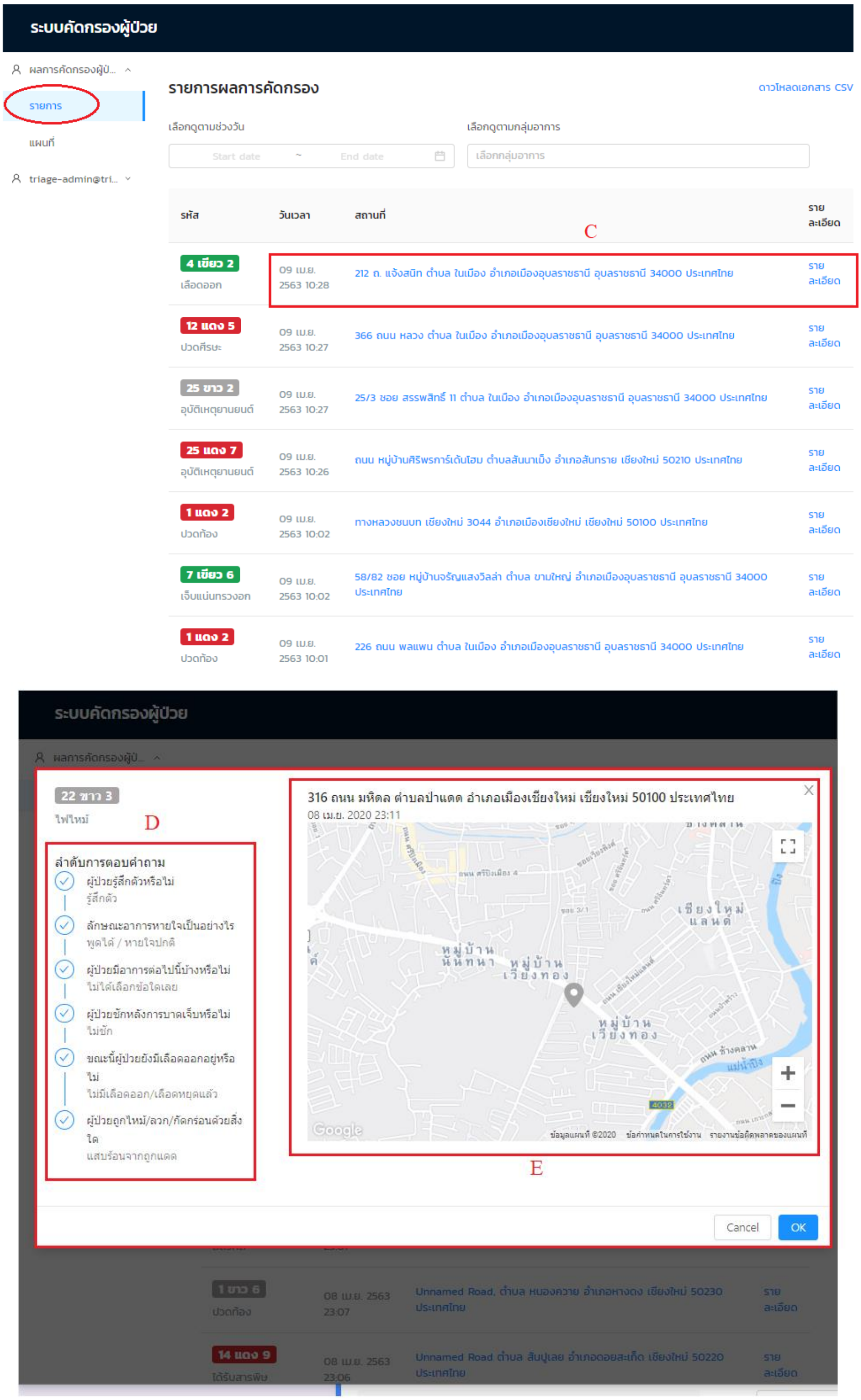


Figure 4: Screenshot of the IDC results list and geolocation information report.

3.2 Patient Triage System Test Results

The fixed version of the Triagist mobile application was improved to support the connection between the application and the current patient triage system. The application was released to Google Play store without being promoted and a total of 178 downloads were reported from the google developer account in September 2019. To analyse the IDC results, the .CSV file was collected from the cloud database of the patient triage system, which contains users' information, including user ID, symptoms, IDC code, patient status, latitude, longitude, address information and date/time of case, respectively. The raw data from the .CSV file is shown in Figure 5, although user ID, latitude, longitude and contact address are omitted for privacy purposes.

	A	B	C	D	E	F	G	H
1	id	module	code	description	latitude	longitude	address/contact	date/time
2		เด็ก	20 ขาว 1	ผู้ป่วยทั่วไป				22/10/2562 14:14
3		ไม่รู้สติ	19 แดง 1	ผู้ป่วยฉุกเฉินวิกฤติ				17/9/2562 9:24
4		ปวดท้อง	1 แดง 2	ผู้ป่วยฉุกเฉินวิกฤติ				16/9/2562 21:20
5		ปวดท้อง	1 แดง 2	ผู้ป่วยฉุกเฉินวิกฤติ				16/9/2562 22:20
6		อุบัติเหตุยานยนต์	25 แดง 7	ผู้ป่วยฉุกเฉินวิกฤติ				14/9/2562 18:04
7		แพ้ยา	2 ขาว 3	ผู้ป่วยทั่วไป				3/3/2563 3:55
8		ป่วย, อ่อนเพลีย,	17 เหลือง 9	ผู้ป่วยฉุกเฉินวิกฤติ				12/9/2562 16:10
9		พลัดหกล้ม	24 เหลือง 9	ผู้ป่วยฉุกเฉินเร่งด่วน				11/9/2562 13:19
10		อุบัติเหตุยานยนต์	25 เขียว 8	ผู้ป่วยฉุกเฉินไม่รุนแรง				11/9/2562 19:11
11		พลัดหกล้ม	24 ขาว 1	ผู้ป่วยฉุกเฉินเร่งด่วน				11/9/2562 13:08
12		ปวดท้อง	1 แดง 1	ผู้ป่วยฉุกเฉินวิกฤติ				11/9/2562 18:42
13		ปวดท้อง	1 แดง 2	ผู้ป่วยฉุกเฉินวิกฤติ				9/9/2562 23:51
14		เจ็บแน่นทรวงอก	7 เหลือง 3	ผู้ป่วยฉุกเฉินไม่รุนแรง				8/9/2562 14:57
15		ตกน้ำ จมน้ำ	23 เขียว 5	ผู้ป่วยฉุกเฉินไม่รุนแรง				7/9/2562 19:21
16		สัตว์กัด	3 ขาว 1	ผู้ป่วยทั่วไป				7/9/2562 7:18
17		ปวดศีรษะ	12 ขาว 1	ผู้ป่วยทั่วไป				8/4/2563 14:03
18		แพ้ยา	2 ขาว 3	ผู้ป่วยทั่วไป				17/9/2562 11:32
19		อุบัติเหตุยานยนต์	25 แดง 7	ผู้ป่วยฉุกเฉินวิกฤติ				5/9/2562 22:16
20		ป่วย, อ่อนเพลีย,	17 เหลือง 9	ผู้ป่วยฉุกเฉินเร่งด่วน				5/9/2562 2:05
21		ปวดท้อง	1 แดง 2	ผู้ป่วยฉุกเฉินวิกฤติ				3/9/2562 15:08
22		อุบัติเหตุยานยนต์	25 เหลือง 3	ผู้ป่วยฉุกเฉินเร่งด่วน				8/4/2563 23:10
23		สำลัก	8 แดง 2	ผู้ป่วยฉุกเฉินวิกฤติ				12/8/2562 16:27

Figure 5: Raw data retrieved from the .CSV file of the patient triage system.

After the application was released to all the participants, the data was collected during the 8-week period from September to October 2019. A total of 128 transactions were found. Missing data such as a duplicate IDC from the same user and no geolocation information was screened and removed. Consequently, a total of 78 transactions of complete IDC commands was analysed in terms of IDC colours, symptoms code, time occurred, and area (Figure 6).

It was found that, in the majority of cases, the IDC was red, which indicated critical emergency patients and nine of the cases presented with abdominal/back/groin pain**.** Most of those with an urgent status were found to be Falls/Accidents/Pains, which were reported in the afternoons, but Strokes and abdominal/back/groin pain conditions reported during the afternoons were classified as being non-urgent three times**.** The general cases when IDC was requested in the morning were found to seven times those of infectious diseases**.** Lastly, the users' locations retrieved from the IDC report showed that cases in urban areas were more frequent than in the countryside. However, most of the critical and urgent cases involved users who lived outside urban areas, while those who lived in towns and cities were classified as non-urgent and general cases.

The data from an IDC report provides important information for emergency resources such as ambulances, medical staff or rescue teams to prepare to offer support in a timely manner to each patient who is classified as an emergency in each area at a time when there is a high number of cases. This means that the data management function can provide useful information to enhance the performance of the pre-hospital process, which not only benefits patients, but also the operation of rescue teams and medical staff. Based on the traditional protocol, when patients called the provincial emergency centre or rescue team, they had to explain their location in detail, but the geolocation system can correctly detect patients' location, which is confirmed by their feedback. Therefore, the geolocation in this protocol can fully resolve the problem encountered by other researchers who applied geolocation to identify the location in emergency cases (Jansen et al., 2015; Weinlich et al,. 2018; Costa et al,. 2019). Although this test did not include an evaluation of the time taken to perform the pre-hospital process, it was confirmed that this function can support and reduce the waiting time or time taken to screen the status of triage patients.

Time is precious in every process, but it is particularly precious in emergency cases. The Triagist application provides emergency doctors with information about patients' status before they arrive at the hospital and the geolocation system in the revised version can help the rescue team to access patients in a timely manner. It is clear that the geolocation system in the revised version increases the performance of the emergency operation by reducing the loss of precious time.

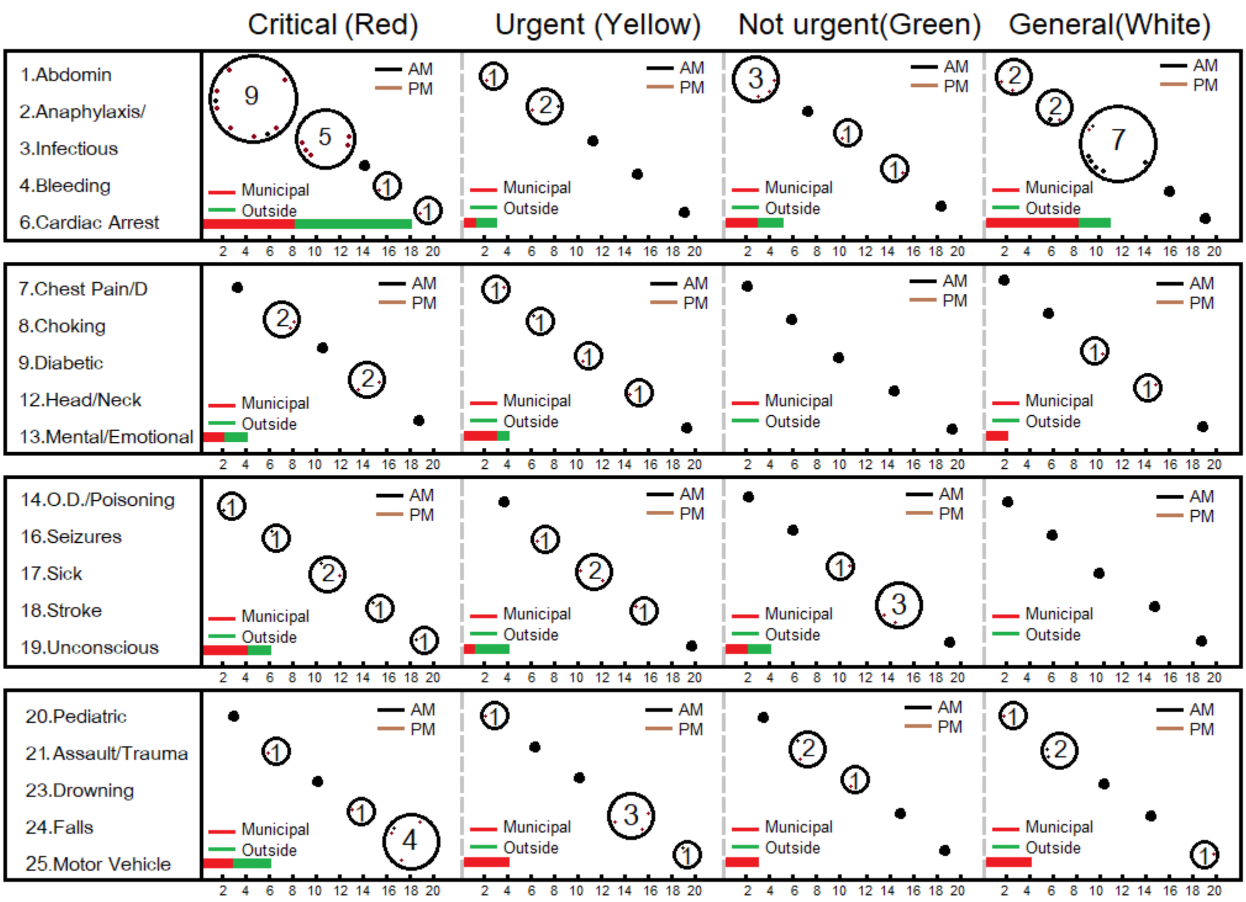


Figure 6 Data retrieved from the cloud database during September-October 2019 after clearing duplication and missing information**.** The numbers in the circles represent the frequency with which cases occur while the dots in the circles indicate the time cases occur, separated into AM and PM**.** The codes 5, 10, 11, 15 and 22 show that no symptoms were reported in the system in that period**.**

3.3 Results of Patient Triage System Assessment

After testing the scenarios, the three groups of participants were asked to complete a usability questionnaire which corresponded to the usability test criteria in Table 4 (Lewis, 2002). The results are presented in Figure 7. The average rating score is divided into three groups of rescue teams, volunteers and medical staff based on their experience of emergency operations.

According to the statistical analysis, the majority of users indicated that they were satisfied, especially the rescue teams, who were the target users of the application. They gave the highest mean score of 4.89 to the statement, “the system has all the necessary functions and capabilities”. When the average scores for the emergency operation experience of each group were analysed, there were almost no statistically significant differences ($p < .05$), apart from the scores in response to questions 1 and 3.

Statistically significant differences were found in the volunteer group in response to question 1, which asked if the system was easy to use. The average rate of the volunteers who had little experience was more positive than the average rate of the highly experienced group with a statistical significance of .05. Meanwhile, the scores of both the medical staff and rescue teams in response to question 3, which asked if users were able to complete tasks and scenarios quickly using this system, were classified by their emergency operation experience, and it was found that the highly experienced group gave a lower score than the group with little experience. The interesting point of the significant difference of each group in response to each criterion was considered and it was found that the experience of the group of medical staff and rescue teams usually depended on their age. This was in contrast to the group of volunteers, whose experience of emergency operations and ages varied.

Although there were no statistical significant differences in the scores of the usability evaluation of the other questions (Q2, Q4, Q5, Q6, Q7 and Q8) by the group who had a great deal of experience of emergency operations, the majority of the ratings showed a similar trend of a higher score by the group with little experience than the highly experienced group.

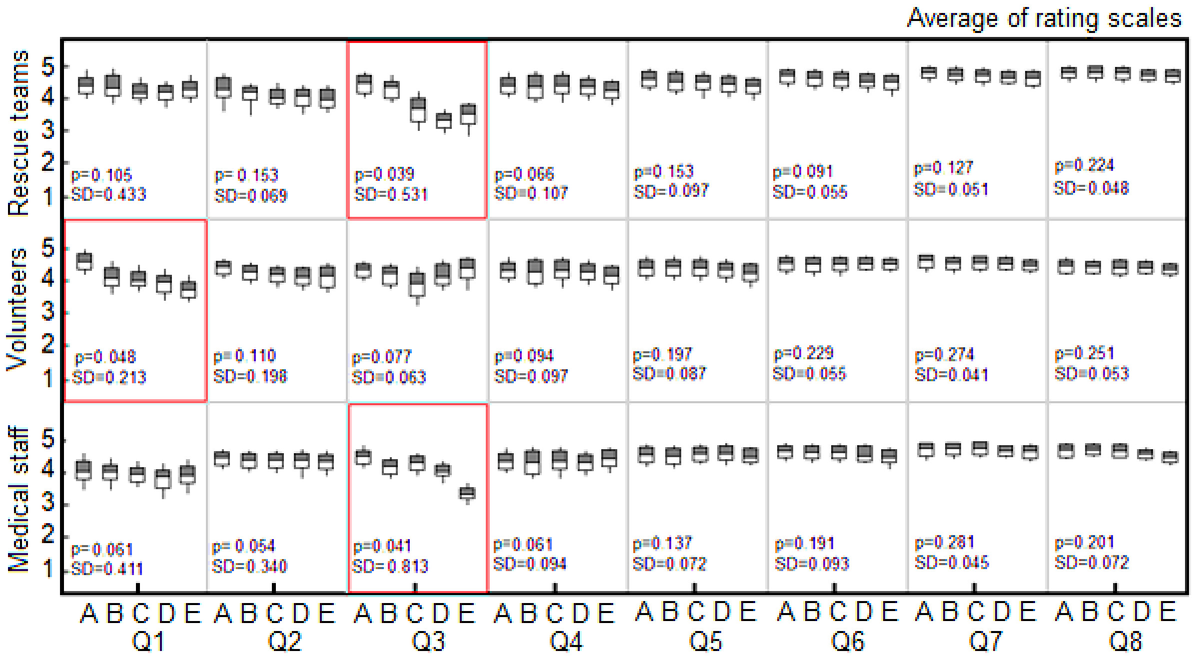


Figure 7: Comparison of the results of users' feedback that correspond to the questions in Table 4**.** Labels A-E represent the number of years of emergency experience of the sample group**:** A; 2-3 years, B; 3-4 years, C; 5-6 years, D; 7-8 years, E; 9-10 years**.**

4. Discussion

The purpose of this research was to extend and revise the Triagist mobile application (Sutham et al., 2020) to support the operation of dispatch centres or rescue teams based on a user-centred design and users' feedback. Design thinking methodology (Thomas, 2009) was used to identify the problems, design appropriate functions and a graphical user interface to support the practical operation of dispatch centres and rescue teams in Thailand. An updated version of the patient triage system was generated based on a literature review and analysis of several emergency medical systems that have been released to support rapid triage healthcare management (Westphal et al., 2020; Christopher et al., 2019; Sumrumeram, 2018; Corey et al., 2016; Romano et al., 2016; Lee et al., 2016). Many researchers have proposed methods to increase the efficiency of emergency medical treatment using smart technology.

As a result, the present study was focused on developing a system that would enable patients' level of emergency to be determined, assess the need for emergency treatment from their IDC results and reveal their geolocation. The system was designed by following the pre-hospital process to increase the efficiency of the emergency medical services (Robertson-Steel, 2006) based on the concept of CBD to request an IDC (Coster et al., 2018). The Laravel framework was used to produce a system that supports a web-based application and cloud base management (Yadav et al., 2019). The eight golden rules of user interface design and Nielsen's ten heuristics were employed to design an appropriate practical user interface to support the tasks of emergency staff (Nielsen, 1994; Cooley, 1989).

The new system for supporting the operation of dispatch centres or rescue teams was connected to the Triagist mobile application, which contains two essential functions. The IDC geolocation function indicates the patient's condition and location address, while the IDC management function enables the emergency staff to sort cases based on receiving a report of emergency cases. These two functions also support rapid emergency management similar to the current smart medical emergency system, especially the incorporation of geolocation services in the application (Weinlich et al., 2018; Sumrumeram, 2018; Romano et al., 2016).

Having developed the prototype, a scenario test was conducted in order to ensure that the emergency staff could use the system to make a quick response in the given scenarios. 68 volunteers, including active members of the rescue teams in Chiang Mai and Lampang, as well as emergency medical staff, were recruited to evaluate users' perception and, hence, achieve another important objective of this study, namely, how to design an application that is suitable for users. Therefore, the usability test criteria in this experiment were those applied by Lewis (2002) for a possible and rapid evaluation. The results were compared between the users in each group, who were separated by their level of experience and satisfaction in the evaluation of the usability test. However, it was found that the group with little experience responded better to the new system than those who were highly experienced. According to these results, the new system can be used in practice by those with little experience to make a response. These were considered to be the factor that influenced the operation of senior responders and caused a low response (Blok et al., 2020). In practice, the senior group were more familiar with traditional methods (manual) than using new technology (mobile). Hence, these results implied that they should be given more information about the purpose of the app and its implementation, instructions of how to use it well and suggestions for simple solutions to technical errors to make them more confident to use the app and reduce the barriers to its use (Keränen et al., 2017).

After the system has been validated, the Triagist mobile application was uploaded to Google play. The IDC results were considered in terms of the density of cases. The analysis of this data will be beneficial for medical staff or rescue teams in terms of allocating medical resources and dealing with urgent cases in a timely manner.

The results of the implementation of both the Triagist mobile application and patient triage system for dispatch centres or rescue teams explicitly show the role of a location-based service linked to the dispatch centre or local emergency services in enabling them to prepare the necessary emergency resources in advance and support administrative tasks. However, this system was not fully operation according to the overview of the patient triage system in Figure 1; therefore, this research can be regarded as a second step of the development based on the use of smart information technology.

The patient triage system developed in this study can be regarded as a tool to support dispatch centres, rescue teams or local emergency services. It also reduces the problems currently involved in applying smart health systems in Thailand (Towse et al., 2004; Suttisak, 2015; Pagaiya et al., 2019). This is a new approach of smart health systems, especially in the emergency services in Thailand, which can support every user who owns a smart phone, although it is more difficult to use a smart system in provincial dispatch centres than in rescue teams or local emergency services due to government policy and other limitations.

Encouraging the use of the application in the first phase may suitably subsidise the work of rescue teams or local emergency services. At least seven rescue teams in northern and southern Thailand have currently agreed to use the patient triage system in their centres. This is an indication of the initial success of smart technology applied to emergency services in Thailand; therefore, the results of the present work may help these teams to continue to improve in the future. It is hoped that this project may be a role model to design the future functions and flow of emergency responses in the pre-hospital process.

5. Conclusion

An extended development of Triagist, a mobile application that supports the operation of dispatch centres or rescue teams, has been presented in this paper. The Triagist mobile application was connected to the current patient triage system on a web-based platform which accommodates the current emergency services in Thailand. One of the contributions of this work is the IDC geolocation function, which identifies patients' condition and location. The IDC management function, which provides useful information to support emergency medical management is another contribution. The existence of these functions enables emergency medical services to identify the location of the emergency, thereby leading to the proficient management of the necessary information to make a quick response. All things considered, the extended version of the Triagist mobile application is a crucial tool to enhance the pre-hospital process and especially reduce the patient's loss of precious time.

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