Coping with environmental challenges: COVID-19 screening station design with standard operation procedure in Thailand

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Abstract. With the continuous need for COVID-19 testing in Thailand, the country lacks appropriate screening and sample-taking facilities. Based on an earlier functional prototype realized by the authors, this research aims to design, plan, and realize a screening station at a safe distance from healthcare facilities to protect those involved from coronavirus infection while the sample is being collected. The design, planning, and realization methodology combines design rationalization processes, including an expert survey based on a prototype analysis, a user survey of potential operators, and an SOP derivation based on government guidelines. Outcomes to improve the resulting station design allow later use changes, improved transportation, and speedier installation in the required locations. Results show the station design improved to the earlier prototype version, suggesting better operation flow and flexible usage, especially in rural regions where the need for isolated testing facilities is prevalent. The constructed screening station design is considered safe, operational, and suitable for implementation near healthcare facilities, offering a low risk of contamination and adaption to individual needs. Its long-lasting character and variable use also help improve health care facilities' future pandemic preparedness. This research is funded through the National Science and Technology Development Agency (NSTDA).

1. Introduction
With vaccination rollout just starting in Thailand, healthcare facilities still need testing facilities that allow sample-taking without interfering with their day-to-day operation [1]. These institutions also need to protect assigned medical personnel and their patients from exposure to coronavirus infection by isolating them from their pandemic-related duties as much as possible. Semi-outdoor screening stations offer the needed spatial separation by taking advantage of reduced exposure risk in areas with prevalent natural ventilation. In addition, such design solutions need to guarantee that assigned healthcare workers (HCW) can examine, consult and sample safely for COVID-19 infections from patients under investigation (PUI). Current practices of using protective personnel equipment (PPE) for sample-taking, especially outdoors, are critically viewed [2]. They have proved cost-intensive, significantly increase hazardous waste volume, and notably quicker exhaustion of medical personnel [3]. The advantage of physical distancing through a spatial separation is that procedures can be performed in a safer and less physically demanding environment. While HCW may still choose to continue wearing PPE, the
precautions offered by the station design support the involved parties' confidence and provide improved standards for safety and job performance.

In public health care institutions in Thailand, free testing for COVID-19 requires a prior screening process that prioritizes only potentially infected patients with plausible, traceable contact with those already infected to be tested. To conduct screening, healthcare facilities must include measures of differentiating PUI and Non-PUI. A standard operating procedure can help perform the required steps for screening and sample-taking, integrating governmental strategies into the COVID-19 screening station design. In addition, with the need for screening facilities in the entire country, the planned design must include an approach for their implementation with budget and quality control.

Consequently, the realization of the created design is intended as a prefabricated off-site construction, with the subsequent transport and assembly on site becoming another critical planning element. Design consideration should also include sufficient flexibility in its foreseen and post-pandemic use. With the built solution of a screening station, which provides an alternative purpose and ultimately improves the preparation for a pandemic of the health facilities, financial and planning efforts for the realization of the station become more sensible and feasible for investors and stakeholders. This research aims to make an off-site screening station available at a moderate distance from healthcare facilities to protect HCW from coronavirus infection while the sample is being collected. The design is intended to match Thailand's healthcare facilities in terms of local conditions and budget constraints through design rationalization from surveys, prototype design adaptation, and case studies. The expected outcome is a viable design solution for current PUI treatment processes during COVID-19 testing by integrating standard operating procedures (SOP) to collect samples with the lowest risk and comply with sample storage standards. Further, including inclusive infographics for people who are not familiar with the Thai language. As a result, the design led to a flexible, transportable, robust, reusable, yet cost-effective solution; test units could be installed near health facilities such as covered or uncovered outdoor areas to avoid potentially infected people needing hospital access.

2. Literature review

2.1. Covid-19 and tuberculosis situation in Thailand

In Thailand, the spread of the coronavirus infection has so far developed moderately. Presently, three waves have been documented, with the third surge recording the highest daily infection numbers [4]. Published by the Department of Disease Control (DDC), the daily reports confirm infection cases relating to PUI tests [5]. Only people with plausible symptoms and contact with the infected qualify for testing. Following government guidelines, free, standard Covid-19 tests prioritize PUI; tests are carried out in state-owned facilities, while private hospitals offer such service for a fee. Both institution types utilize screening and sample-taking practices via on-premises, off-premises, and walk or drive-through tests, with many representing temporary impromptu solutions [6]. Ensuring safety is one of the many challenges that hospitals face. Medical staff must rely on personal protective equipment (PPE) to avoid becoming infected when treating potentially affected patients. With the spread of the pandemic, the need for PPE has risen sharply, resulting in supply bottlenecks, rising costs, and an increase in hazardous waste [3]. Besides Covid-19 infection, the country is also exposed to other airborne infectious acute respiratory diseases, such as Tuberculosis, with an annual death rate of 14 per 100,000 people [7]. Requiring continuous sample-taking and treatment, health care facilities face similar difficulties as with the current pandemic, where physical distancing is needed to prevent disease transmission [8].

2.2. Safety measures

Social or physical distancing is an effective non-medical measure to prevent direct and indirect person-to-person transmission. Retaining a physical distance between people and reducing the frequency with which people come into close contact [9] are helpful when transmitting infectious diseases through droplet contact. In terms of social distancing, keeping 1.5 meters and avoiding large gatherings is
advisable [10] to flatten the epidemic peaks in the epidemic. For mitigating fomite infection with the coronavirus, exposed surfaces with reduced detailing of joints or corners enable simple and effectively regular cleaning [11]. In Thailand, national indoor climate requirements for airborne infectious diseases suggest controlling air quality in rooms where infected patients and HCW are present simultaneously [12]. Air treatment should comply with airborne infection prevention regulations used in highly contagious disease facilities, such as utilizing pressure-less air to remove potentially contaminated air volumes around patients. Or pressurized air to protect areas where medical personnel are active [13]. For effective air filtration, highly efficient particle-absorbing (HEPA) filter systems can be seen as another measure for infection control [14]. Information on designing and planning separate treatment facilities for treating potentially infected coronavirus patients is also provided by international organizations. For example, a WHO design guideline illustrates the need for strict physical distancing between medical staff and potentially infected people and the need for air control, including the utilization of natural ventilation in semi-outdoor areas [11].

2.3. Design rationalization
In general, building design describes the comprehensive performance of architects, engineers, and related specialists in building construction [15]. The design rationalization method can ease restrictions through partial analysis and synthesis to avoid unjustified deviations through simplification, reduced complexity, and technological possibilities. Such can be used in several ways to construct the content and process of problems. Survey-based research is often used in various medical areas to gather information about behavior patterns and attitudes towards various clinical trials and diseases [16] and design-related studies, such as spatial programming purposes, or to expand scientific knowledge in social-related research. With analysis techniques connected with prototype developments and the associated redefinition of design requirements, significantly better design solutions can be achieved. As a pre-implementation for testing a concept or process, a working prototype represents the main features that describe the use and appearance of a planned design [17].

2.4. Standard operating procedure (SOP)
A Standard Operating Procedure (SOP) is a sequence of step-by-step instructions for performing routine tasks to achieve efficiency, quality, and reliability while reducing misunderstandings and non-compliance with regulations. With the pandemic developing in Thailand, public hospitals offering COVID-19 screenings have arranged a screening procedure to align with government published guidelines. An example of the established process is from Ramathibodi Hospital [18], with detailed procedures for patients and medical staff throughout the process. Its associated steps are illustrated in Figure 1, documenting a total of six steps required to complete the PUI screening and sampling process, involving employees with different levels of expertise for each phase. They include a doctor, pharmacist, nurse, and administrative staff. While consolidation is possible, keeping these phases for the COVID-19 test station will likely aid patient flow in the overall process. In addition, with the illustrated steps, the SOP suggests that non-PUI can also be treated, potential use as a clinic for acute respiratory infections (ARIC).
3. Methodology

The research methodology for realizing the screening station design involves combining design rationalization processes to synthesize a design proposal. Essential elements of the rationalization process include an expert survey based on a prototype analysis, a user survey of potential operators, and the SOP derivation from appropriate, accessible sources.

3.1. Expert survey

Expert surveys were carried out based on individual interviews. It consisted of one-on-one interviews with medical and construction experts who were already engaged in the development process of the prototype, together with a post-implementation review after installation at Loeng Noktha Crown Prince Hospital in Yasothon Province [19, 20] that also included the operating staff. Accordingly, with the experts involved in the prototype realization and testing, only a few numbers with a specific knowledge base were researched. When referring to earlier prototype development by the authors, several areas for improvement were identified from the earlier design solution, relating to the screening and sample-taking process, the overall design requirements influencing assembly and transportation of the screening station, and the consideration of extending the use beyond the pandemic outbreak. Study outcomes showed that the practiced one-step screening and the sample-taking process are vulnerable to delay the needed time to conduct the procedure. With different steps in the process undertaken by diverse staff, integrating staff-related workflow into the design may help make the operation more time-efficient and safer for the medical staff involved. As a result of the scrutiny, successfully tested features were selected to retain the new design. They include using the semi-outdoor environment for patients supporting airborne droplets dispersion, the physical distancing between PUI and HCW via spatial...
separation, the air control of the HCW’s interior spaces, and utilizing a pressurized air conditioning system with a HEPA filtered air supply.

Further, the reduction of surfaces on the stations outside exterior supporting effective cleaning, the transportation and assembly using a single flatbed truck with crane function, and the adherence to given building code requirements that allow for a permit-free realization. The consideration of extended use should also make the design more flexible and enable anticipating further functional use of the station's cabins, such as vaccination procedures or after a pandemic as clinics for acute respiratory infections. Thus, the interior aims to be multifunctional, with interchangeable activities and further examination and vaccination activities. In addition, a broader disease spectrum related to acute respiratory infectious diseases, such as Tuberculosis, is considered, allowing the design of the screening station to be utilized as a post-pandemic clinic for acute respiratory infections (ARIC). Considering expanding the inside operating staff from two to six while keeping the initially intended means of transport, the constructive improvement focuses on optimizing the COVID-19 test facility by keeping dimensions and weight within the vehicle's anticipated load capacity. For its transportation on the platform of a medium-sized truck, any protrusions that go beyond these dimensions must be dismounted. For lifting purposes, the integration of crane hooks should be considered part of the design and weight restrictions. Lightweight construction further allows maneuvering on the ground, ensuring installation at versatile site situations. In addition, the development should reduce the number of components that need removal during transportation to a minimum for improving the assembly on-site.

3.2. User survey
A second survey was conducted among health officials selected hospitals and healthcare facilities in Thailand who expressed an interest in receiving a COVID-19 screening station based on the new design. With gained experiences from the prototype, the low sample number on the user survey is considered acceptable because the facility is still relatively uncommon, resulting in limited in-depth user experience. Altogether, eight consultations were carried out with the help of a questionnaire to gain insights into prevalent screening and sampling procedures or existing guidelines and requirements for personnel safety. All respondents indicated that physical distancing is considered mandatory in their professional practice whenever possible; self-made constructions, such as plastic foils are wrapped around PVC pipe frames, are typically used as room dividers. The scarce supply of PPE also addresses the disadvantage of constantly wearing it in a tropical climate situation. Concerned about the virus's possible spread, primarily putting medical staff and operations at risk, all surveyed agreed to the need for an isolated screening station at their facility. Respondents agreed that the screening facility should not be located indoors within an existing facility. All participants confirmed that prior screening must be performed as only confirmed PUI testing would be free, thus agreeing to the proposed SOP application. Given budget constraints and the need to downsize the design, a majority insisted that the design retain consultation and sampling functions, while only some agreed that just one cabin would be sufficient for sampling. Given the future post-pandemic situation, all eight participants confirmed that their healthcare facilities would continue to need the screening station. Several respondents felt, if successful in use, it was likely to be used as a permanent facility for airborne respiratory infections such as Tuberculosis, with the preferred location between 10 and 20 meters from the existing facility. Five participants prefer the screening station to be in nearby semi-outdoor areas, and two of them like the unit to be fully outdoor. The average desired operating temperature for the interior cabins should be 25°C; any room temperature without air conditioning would generate sweating, increase employee safety concerns, and reduce concentration on work. All participants confirmed that they are familiar with the operation and maintenance of an air supply system. They have also confirmed they have had experiences with hyperbaric isolation rooms in healthcare facilities. Respondents also confirmed that they are familiar with the steps and processes involved in cleaning and disinfecting to avoid contamination in a hospital facility.
3.3. Standard operating procedure (SOP)
By aiming to separate potentially infected and swiftly guide them towards COVID-19 testing, the screening station interior foresees six workstations in the design that can be flexibly used. The studied SOP steps for PUI can be performed linearly; assuming the consultation with the doctor shows that a PUI does not require a COVID-19 test, the now Non-PUI can be concluded after receiving any medication that may be required. The confirmed PUI will continue to conduct the swab test and clarify further steps. The considered treatment flow allows alternative possibilities of utilizing the COVID-19 testing station during and after a pandemic. For example, with the limitation of staff and space or the increase of PUI waiting for sample taking, temporary rearrangements of the cabin function and staff utilization can be made.

4. Results and discussion
The COVID-19 screening station's design result, construction completion, transportation, and installation on the predestined site are described in the following. It includes a summary of an interview with the operator at Mae Sod Hospital, to which the station was delivered and installed on January 21, 2021. In addition, some of the significant design and planning features are shown in Error! Reference source not found. and 3, showcasing a perspective view and a floor plan of the facility for reference.

Figure 2. Perspective illustration.

Figure 3. Floorplan drawing.
The SOP for screening and sampling was initially used when the numbers of PUI visiting the facility were moderate. Feedback from the managing HCW confirmed the SOP was successfully implemented, with all HCW working safely from inside the cabins. In the event of an increased number of people and long waiting times during the consultation, the counter functions for "swap test" and "follow-up" were relocated to a separate stand to utilize additional consultation counters. Yet, the original setup was still preferred as the assigned staff could work from the station. Since all front counters are designed for several functions and allow changes, the design demonstrated flexibility if necessary. Completed in December 2020, the air conditioning system was tested for pressurization and filtration and certified as a laboratory clean room to fulfill standard requirements for use. Delivered to the selected healthcare facility, Srisangwan Hospital in Mae Hong Son Province, in April 2021, Error! Reference source not found. shows parts of the structure lifted from the truck. Figure 5 shows the screening station's location adjacent to the hospital, at a less-frequented area, in safe and sufficient distance from the main entrance and to enable separate access to the nearby radiology department when needed. Transportation and placement of the station were unproblematic, with improved installation compared to the prototype. Due to damage caused to the connector of the separated air duct, its needed replacement caused the only delay during assembly.

Figure 4. Transportation of station segments.

Figure 5. Installed COVID-19 testing station in front of Srisangwan Hospital in Mae Hong Son.

Operating instructions have been drawn up and handed over to the operator for safe and reliable use. During the day, the screening station is also used for COVID-19 screening and sampling and for treating tuberculosis patients; its post-pandemic use as ARIC is already planned. In addition, the facility is used for medical consultations outside office hours, proving its flexibility for various applications in
healthcare. With alterations to the inherent cubicles, including each counter having spare openings for attaching gloves, an operable window, and an outdoor counter for storing utensils, its functionality and versatility in use have improved.

5. Conclusions
The design and construction of a COVID-19 screening station were implemented for semi-outdoor use near health facilities in Thailand. Based on a design rationalization method via the prototype analysis, expert, and user survey results to meet the screening requirements and improve the operational flow, it integrates a standard working procedure for COVID-19 screening and sample-taking. A prefabricated screening station was transported and installed at a hospital to test its use and suitability for local conditions and budget constraints. The screening station provides considerations for appropriate use, transportation, and installation based on previous prototype testing. Thus, the screening station enables the proper execution of examinations and sample-taking while at the same time ensuring a sufficiently safe working environment and avoiding the extensive need for PPE. Results indicate the design solution was adequately planned. Expert and user surveys and implemented SOP significantly improve the functionality with the new design solving the addressed issues, fulfilling the prospect of improving the needs of existing healthcare facilities in terms of practical use, air treatment, maintenance, and cost aspects. Above all, the separation from existing healthcare facilities that operate at locations in the vicinity avoids unnecessary infections and provides an efficient physical distance between PUI and the treating HCW. Future work will focus on developing design guidelines to facilitate dissemination.

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