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RESEARCH ARTICLE

Integrating Lean Principles in Fire Safety Engineering for Private Al-Quran Memorization (Tahfiz) School Buildings: A Conceptual Framework

S. R. Salman[1], N. S. Suhaimi[1], S. M. Phuspa[2], S. Rahmawati[3], A. Ramli[1]*

[1]Faculty of Industrial Sciences and Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, 26300 Kuantan, Pahang, Malaysia
[2]Faculty of Health Sciences, Universitas Darussalam Gontor, Jl. Raya Siman, Demangan, Siman, Ponorogo, East Java 63471, Indonesia
[3]Department of Environmental Engineering, Faculty of Civil Engineering and Planning, Universitas Islam Indonesia, Jl. Kaliurang KM 14.5, Yogyakarta 55584, Indonesia

ABSTRACT - The adoption of lean principles and the establishment of a lean culture are continuing trends in both construction and post-construction buildings. This paper will examine how lean principles and fire safety management practices are integrated into the design, supply, construction, occupation, refurbishment, and demolition phases of the Private Al-Quran Memorization (Tahfiz) School (PTS). A deadly fire at Pusat Tahfiz Darul Quran Ittifaqiyah, a religious school in Kampung Datuk Keramat, in 2017, and other fire incidents that caused heightened attention on safety in these institutions led to the start of this study. This poses a significant challenge that requires immediate attention to the infrastructure and fire prevention systems of PTS. It is important to effectively implement fire safety measures to protect people, school buildings, and property from the catastrophic effects of fire. To address this issue, Lean Principles are being adopted in fire safety management, with a focus on the performance of the PTS infrastructure as a prevention approach. Lean Principles are commonly used in Lean Manufacturing, Lean Design, Lean Construction, and Lean Maintenance, and have been widely accepted by professionals worldwide. Prevention through Design (PtD) can be initiated as a general prevention principle, with various Lean Tools implemented throughout the PTS building lifecycle, including designing, construction, occupying, demolishing, and modification processes. Despite the integration of Lean Principles into fire safety engineering is yet to be studied and introduced effectively, the framework has potential benefit in developing legislation, rules, guidelines, and good practise in the government/regulatory body that could enhance the fire prevention system in the PTS.

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1. INTRODUCTION

The rising demand for Tahfiz institutions in Malaysia has grown, and more Tahfiz institutions have been established, Misbahrudin and Noor [1]. The tahfiz study centers were born and, some of which were established by the government, and some of them were developed by the private sector, also known as Private Tahfiz School (PTS). This follow by the wave of the tahfiz education system which is placed so close to the government administration, Samadi, Widiantari, et al. [2]. On the other hand, the safety of students in tahfiz schools is of paramount importance, as demonstrated by the tragic fire of Pusat Tahfiz Darul Quran Ittifaqiyah Kuala Lumpur in 2017. Following to the fire incident, about 50% of the 956 tahfiz schools that were inspected by the Malaysian Fire and Rescue Department in 2017 were deemed dangerous and posed a fire risk that can take lives. To comply with safety rules, these PTS had been addressed concerns such as outdated building structures, a lack of escape routes, and inadequate fire safety equipment. Despite facing challenges in the past, tahfiz institutions have maintained their position within the muslim community in Malaysia, NH Hamzah et.al [3].

Following to fire incident tragedy in 2017, there were various kind of initiatives and effort to establish the Fire Safety Campaign Tahfiz and Pondok Fire Squad Program to enhance awareness and safety in tahfiz centers and folk religious schools in Malaysia to prevent the recurrence of fire incidents. The training modules included the rescue and evacuation procedures, the use of fire extinguishers as well as theoretical and practical training to deal with emergencies. However, the efforts from the government through this program not achieve the vision of reducing the statistics of fire incidents in these PTS educational institutions as Malaysia still witnessed various severe incidents and fire safety issues in the PTS. Table 1 shows the non-exhaustive cases which occurred in 2022. With the unchanged fire statistics for the past five years and the continuous growth of PTS, the idea of creating a cooperative fire safety management system is something urgent to be highlighted.

This study is designed to develop a conceptual framework for implementing Lean Principles and its Tools in Fire Safety Engineering. The ILP-FSE framework assess all potential fire safety measures at every phase of the PTS infrastructure for the security and safeguarding of individuals, infrastructure, property, and the natural environment. The

***CORRESPONDING AUTHOR | A. Ramli** | ✉ azizanramli@umpsa.edu.my

process additionally has the potential for developing legislation, rules, guidelines, and other requirements in the government/regulatory body, as enforced in the UBBL 1984 [4].

Table 1. Fire incidents in Private Tahfiz School (PTS) in the year 2022 (non-exhaustive)

Date	Fire Incident	Source
22 Jan 2022	Pondok Maahad Assyatirie, Dulang Besar, Yan, Kedah. The PTS infrastructure on the top floor of the two-story hostel, which was used for outdoor activities, broke out, causing slight damage. However, no one was hurt, as all occupants were outdoors.	https://www.bharian.com.my/berita/kes/2022/01/914581/15-pelajar-terselamat-asrama-maahad-tahfiz-terbakar
23 Jan 2022	Maahad Tahfiz Assyatirie di Kampung Dulang Besar, Yan. 240 all occupants escaped from a fire at the hostel of the PTS's Sungai Dedap branch in Yan, Kedah, at about 4.50 pm, however, the fire involved no casualties.	https://www.kosmo.com.my/2022/01/23/maahad-tahfiz-assyatirie-induk-pula-terbakar/
28 Feb 2022	A total of 40 all occupants including a teacher at Maahad Tahfiz Al-Quran Al Mushaf Labok faced an anxious moment when their dormitory caught fire. The damage to the dormitory PTS infrastructure was estimated at RM70,000, however, the fire involved no casualties.	https://www.sinarharian.com.my/article/190146/berita/semasa/40-pelajar-guru-cemas-asrama-tahfiz-terbakar
23 Apr 2022	74 All occupants from the Maahad Tahfiz Sulaimaniyyah Rayyaj Bombalai. Dormitory 70 percent burnt down and were destroyed by fire however, the fire involved no casualties.	https://preprod.astroawani.com/berita-malaysia/asrama-maahad-tahfiz-terbakar-74-pelajar-hilang-tempat-tinggal-358306
22 Jun 2022	Pusat Tahfiz Dar al-Fawzan, Sri Iskandar, Perak. Six all occupants escaped unhurt after a fire broke out at Tahfiz in Jalan Iskandar Bistari, The fire damaged 15 percent of the room.	https://www.astroawani.com/berita-malaysia/asrama-pusat-tahfiz-terbakar-6-pelajar-terselamat-367587
24 July 2022	33 out of 100 wooden huts at the Madrasah Al-Imaniyah tahfiz in Kampung Darat, Jalan Sungai Ular, Kuantan, Pahang were destroyed in a fire. No casualties were reported as all occupants were on their break.	https://www.nst.com.my/news/nation/2022/07/816076/33-huts-madrasah-al-imaniyah-tahfiz-school-destroyed-fire-nsttv
17 Aug 2022	A dormitory room housing 12 males all occupants of Maahad Tahfiz Al Abidin, Jalan Jenun was destroyed in a fire. The incident around 10 o'clock caused 80 percent of the dormitory PTS infrastructure destroyed, however, it involved no casualties.	https://www.hmetro.com.my/mutakhir/2022/08/872865/asrama-terbakar-12-pelajar-maahad-tahfiz-selamat
14 Sep 2022	The fire involved a three-stories dormitory PTS infrastructure on the second and third levels of Maahad Tahfiz As-Sofa Seremban, Dataran Sentral, N. Sembilan, however, it involved no casualties.	https://www.utusan.com.my/nasional/2022/09/asrama-tahfiz-terbakar-pelajar-selamat/
25 Oct 2022	36 tahfiz all occupants and four dormitory teachers where they lived were involved in the incident at Maahad Tahfiz Sulaimaniyyah, Kampung Sungai Padang, however, it involved no casualties.	https://www.astroawani.com/berita-malaysia/asrama-maahad-tahfiz-terbakar-74-pelajar-hilang-tempat-tinggal-358306

(Source: Various)

A Fire safety-engineered design offers greater flexibility or significant cost reductions and provides a safer design than a structure that adheres to standard guidelines. As a result, the integrated Fire Safety Engineering-Lean Principle (ILP-FSE) Framework proposal constitutes a relatively niche subject matter, and it is unlikely for researchers to find this subject in any research topic within Malaysia as well as globally.

2. RESEARCH METHODOLOGY

The objective of this paper is to demonstrate how lean principle approach can properly be used in a cycle of building started from design, construction, occupation, maintenance and demolition of the building using a case study of fire safety in PTS based approach. This research adopted a systematic literature review (SLR) methodology, Chand [5] to analyze the PTS case studies on the framework of Lean Principles integrated with fire safety. In this PTS Case-Study, a data collection strategy was developed to identify and analyze the existing literature on lean principles and fire safety in building life cycle and its influencing factors for the integrating framework. Data collection focused on scientific articles published in specialized journals in the lean principles and fire safety of school during the past 5 years. This mixed research methodology, Fetters and Tajima [6] combined a quantitative and qualitative approach, by personal interviewing the chosen professionals in the qualitative approach. Focus groups discussion (FGDs) as qualitative research methods

also adopted to validate the framework, H. M. Yusoff et al. [7]. FGD discuss focus group interviews as a useful instrument for qualitative data collecting, including their origins, purpose, justification, moderator characteristics, major phases, and criteria. It concludes that well-trained researchers can achieve a common understanding, O'Sullivan [8]. FGD bring together persons with comparable backgrounds or experiences from various backgrounds including the relevant authorities, designers, consultants, practitioners, and lecturers in building construction sector are used to discuss a topic of interest. The group is led by a moderator, who offers themes for debate and facilitates a vibrant and natural discussion among a small group of participants, typically 6 to 12, Nind et al. [9]. FGD is used in a pre-structuring phase of the research to check if all possible dimensions of a topic are in the awareness of the researcher or when a researcher wants to collect different points of view or judgments of experts, Gundumogula [10].

3. LEAN TOOLS & FIRE SAFETY ENGINEERING (FSE)

The fire safety engineering aspects of PTS buildings that will be discussed further in this research include the stages of design, construction, maintenance, and change. The design phase, which precedes construction, involves the conceptualization, planning, drawing, and specification of the PTS infrastructure. This stage sets the foundation for the building process, which encompasses the procurement and completion of the structure. The construction phase is typically referred to as the implementation stage. Following this, the occupation stage represents the ongoing maintenance of the building. The change stage involves alteration, adaptation, refurbishment, and repurposing, covering all aspects of the process, IFSS [11].

Lean principles, originally introduced by Toyota to enhance manufacturing processes by reducing costs and improving productivity, are often associated with the term "lean." Though commonly seen as a production strategy, lean principles have also been shown to offer advantages in safety and protection. Lean safety is a systematic approach to eliminating waste in tasks and processes that may impact safety or health. Lean tools such as 6S, 5 Whys, Total Production Management (TPM), Kaizen, Poka-Yoke, Kanban, Process Mapping (PM), Computerized Maintenance Management Systems (CMMS), and Failure Mode and Effect Analysis (FMEA), among others, are widely applied in maintenance management, Dragone et al [12]. The core ideas of Lean emphasize continuous improvement in workplace safety, with Kaizen and Kaizen Events driving this approach by recognizing safety issues and fostering an ongoing effort to enhance safety at work, Aziz and Hafez (2013b) [13]. Lean tools, particularly the 6S system, play a crucial role in improving workplace safety. This system includes processes such as Sort, Straighten, Shine, Standardize, and Sustain, all of which contribute to creating a clean and organized workplace. Built-in safety features within the 6S approach, like the elimination of waste and proper organization of the workspace, reduce the likelihood of accidents, including fires. Cleanliness is directly linked to reducing fire hazards, as clutter can obstruct emergency responses. Standardizing procedures and minimizing process variability also reduces the chances of errors and accidents. Commitment to these principles ensures that safety improvements are sustained over time. Lean principles applied to safety focus on value, efficiency, customer satisfaction, and loss removal, further contributing to a safer working environment, Aziz and Hafez (2013b) [13].

Fire safety engineering (FSE) is defined as the application of scientific and engineering methods to safeguard individuals, property, and the environment from fire, as per BS 7974 [14]. This performance-based approach plays an integral role in the design, implementation, and management of fire safety systems. The primary objectives of FSE are to save lives, protect property, and preserve the environment, including heritage buildings and natural resources, while identifying and mitigating fire-related risks. Building fire safety is often addressed with unquantified systems, which may not fully account for current fire hazards. FSE is categorized into four main areas: fire safety strategies, infrastructure standards, related regulations such as the UBBL 1984 [4], and firefighting operations. Failure to consider these areas during the infrastructure development stages can compromise fire safety at various stages of the building's life cycle. The key objectives of fire prevention include protecting activities, preventing damage to infrastructure, and ensuring life safety in the event of fire. The automatic fire detection systems, part of the detection and communication principle, alert occupants and relevant authorities through predefined communication channels. The occupant protection principle ensures safe evacuation and protection from fire hazards, while the containment principle aims to restrict the fire's spread by confining it to a limited area. Suppression and control measures follow the extinguishment principle, with systems installed to manage the fire effectively and, the Fire-fighting personnel are responsible for extinguishing the fire, IFSS [11].

The relationship between Lean principles and fire safety engineering is crucial for enhancing the overall safety of PTS infrastructure. The primary focus of PTS infrastructure design is the safety of occupants during a fire, and every aspect of the infrastructure, including its architecture and usage, impacts fire safety. Applying Lean principles to fire safety means reducing costs and waste while improving safety and fire safety engineering (FSE) effectiveness. A comprehensive framework for fire safety management should be developed to guide all stakeholders in the PTS facilities. This framework, as proposed by Hassanain et al. [15] will serve as a valuable reference for fire safety management practices. To ensure fire safety at every stage of the PTS infrastructure life cycle, all relevant stakeholders must develop FSE plans within the Lean-FSE Framework. This LP system emphasizes continuous improvement and requires leadership commitment. When implemented correctly, Lean principles can lead to improvements in safety, quality, and efficiency while adhering to approved materials, project specifications, and construction drawings, thus ensuring that fire safety is maintained throughout the life cycle of the building.

The Lean principle in fire safety design emphasizes making decisions that improve the fire-related characteristics of PTS infrastructure, driving the design process Węgrzyński et al. [16] Under this principle, the Department of Safety & Health (DoSH) Malaysia established guidelines in 2017 for managing safety, health, and welfare in construction projects (OSHCIM) [17] PTS buildings must be designed with fire safety in mind to minimize fire risks. Hassanain [18] summarized the five key processes that form the framework for assessing fire safety in dormitories and housing facilities. These processes include documentation and evaluation, establishing audit checklists, conducting safety inspections, focusing on potential improvements, and implementing safety measures to address non-conformities. The Prevention through Design (PtD) stage involves risk assessment and the identification of safeguards to prevent the occurrence of fires and limit their effects. PtD addresses product safety, electrical safety, combustibility, and the smoke-producing properties of materials used in the construction of building facilities, IFSS [11]. It also considers human behaviors, such as cooking, the use of electrical appliances, the storage of combustible materials, and vandalism, which can contribute to fire hazards. Research on human reactions during evacuation provides valuable insights for improving fire safety design in PTS buildings.

The Detection and Communication principle in fire safety engineering involves using automatic systems to detect fires, trigger alarms, and communicate with occupants and authorities. This principle is integrated into the planning of the PTS Emergency Layout Plan, taking into account the building's internal geometry and wayfinding systems, as outlined by IFSS [11]. Early detection and effective communication are essential for ensuring the safety of all occupants during a fire emergency. The Occupant Protection principle is concerned with ensuring the safe evacuation of all individuals in the event of a fire. This involves designing systems that facilitate simultaneous or phased evacuations, including the use of emergency exits, staircases, and evacuation elevators, as well as ensuring proper signage and assembly points. Fire safety design also includes smoke and fire containment features, such as fire barriers and water sprinklers, and considers occupant characteristics, such as their ability to evacuate safely, behavioral responses, and external assistance for individuals with disabilities, IFSS [11]. The Containment principle focuses on both passive and active fire containment methods. The design must account for the time needed to contain the fire, allowing enough time for occupants to evacuate and for firefighting services to respond. The design should also consider the proximity of fire services and the structural integrity of fire-resistant components, such as fire-rated glazing, walls, and roofs. These considerations are essential to ensuring the safety of occupants and minimizing the fire's impact on the building.

Finally, the Extinguishment principle addresses the role of firefighting services in containing and extinguishing the fire. The design should ensure that the fire service has adequate access to the building, with clear routes and necessary equipment such as dry and wet risers, water sources, and fire extinguishers. Proper firefighting infrastructure, including visualization systems, ensures that fire services can respond effectively to a fire emergency, IFSS [11].

4. FSE LEAN CONSTRUCTION PRINCIPLE

During the construction phase of a PTS building, several parts of the containment system and infrastructure may still be incomplete or inoperative. In addition to addressing workers' behavior, the number and types of employees, and the roles of other personnel, other factors such as staff training and accreditation, security staff, work procedures for site personnel, and the capability of rescue teams must be considered. Temporary evacuation protocols and procedures for adapting management and interactions, in line with the gradual completion of the project, should also be factored into the fire safety strategies from the design stage. These elements, along with regular walk-downs to ensure compliance with the FSE Principle, are crucial for a successful construction phase. The quality of a building project can greatly benefit from the application of Lean Construction (LC) tools. In addition to strictly adhering to the FSE Principles, the 6S method and continual improvement practices should be implemented to ensure a safe workplace. Lean tools focus on reducing waste through the concepts of Mura, Muri, and Muda. Mura refers to unstable behavior or variability, while Muri represents excessive or unreasonable burdens. Muda, in turn, involves eliminating waste in various forms, including transport, inventory, motion, idling, excessive production, overprocessing, errors, and skills. By enforcing inspections and adhering to FSE standards, Lean Construction projects tend to be easier to coordinate, safer, and more cost-effective, offering superior safety and quality performance. Implementing LC tools benefits contractors and enhances client satisfaction, as highlighted by Marhani et al. [19]. The general steps for applying LC principles by Aziz and Hafez [13] in FSE include:

i) Value Determination through Client's Perspective: Listening to the customer's needs and developing insights to place the customer at the center of the process is key. It is vital for the project team, which includes the main contractor, subcontractors, engineers, architects, and the builder company's owner, to understand and appreciate the value of FSE from both the client and regulatory perspectives. This approach helps reduce waste and ensures the project meets client expectations.

ii) Set the Value Stream in Place: The next step is to establish the procedures that will deliver value, starting by understanding stakeholder perspectives and addressing sources of waste. A value stream map helps identify the value flow in a construction project by depicting resources and information that pass through various stages, along with data such as task duration or material ordering frequency. This map facilitates understanding of required resources, materials, and labor, ensuring that waste is reduced and value is added.

iii) Establish a Work Process Flow: An efficient LC project should have an unaffected, continuous, predictable, and reliable workflow. To achieve this, collaboration and coordination among the various project parties, including trade groups, the client/PTS owner, and project managers, are crucial. Everyone must perform tasks in the appropriate order for the construction process to run smoothly. For example, FSE construction cannot proceed without sufficient design drawings in place. Communicating any delays or ahead-of-schedule progress helps avoid inventory excess, wasted resources, and idle time, contributing to compliance with the FSE Principle.

iv) Utilize "Pull" Scheduling and Planning: Lean Construction adopts a "pull" method, also known as just-in-time (JIT), where production is driven by actual demand rather than predicted demand. The "pull" approach ensures that materials, workers, and other resources are available when needed, fostering a more reliable and predictable workflow. Collaboration between all project stakeholders is essential for establishing work, materials, and labor timelines.

v) Seek Continuous Improvement through Kaizen: Kaizen, meaning "transforming for the better," is an essential component of Lean methodology. It focuses on continuous improvement at every stage of the development process, ensuring that potential for betterment is identified and addressed. For a project to succeed and meet the owner's expectations, the collective participation of all involved, built on trust and collaboration, is necessary.

5. FSE LEAN REFURBISHMENT

Lean principles focus on modifying construction projects before work commences to ensure that systems are properly specified and can be installed effectively. Often, passive fire protection systems are overlooked, which can make their installation more difficult and costly if added later. When the PTS infrastructure undergoes modifications, all fire safety strategies and procedures from both the design and construction stages must be reviewed and adapt. Fire risk assessments should include potential hazards in both the modified structure and adjacent areas, as outlined in IFSS [11]. During renovations, the ongoing operation of current systems is supported through detection and communication strategies, with temporary systems and appropriate signage included. Modifications to escape routes must also account for an increase in the number of occupants, ensuring compliance with the Occupant Protection Principle. Fire safety procedures must be integrated from the design and construction stages to contain the fire effectively during renovations and ensure adherence to the Containment Principles, IFSS [11].

The FSE Lean Maintenance Principle emphasizes the importance of ensuring that fire safety facilities are operational during the PTS infrastructure's operation. Fire incidents in PTS environments can cause significant property damage, injuries, and fatalities, as highlighted by Irajpour et al. [20] In enclosed spaces like dormitories or classrooms, fire and smoke pose even greater risks as described by Isobe et al. [21] The maintenance team must ensure that the infrastructure’s safety, performance, and functionality are maintained, as discussed by Dragone et al. [12]. The Prevention Principle covers the maintenance of equipment, scheduling work, procuring materials, and ensuring the performance of tasks. The maintenance team must guarantee that equipment is available and operates in line with the prevention and detection principles when the PTS infrastructure is in use, IFSS [11]. Regular inspections of passive fire installations, service penetrations, and fire protection systems must be carried out, and maintenance teams must understand how to maintain compliance. Qualified fire servicing staff must identify gaps in existing systems and evaluate architectural plans to ensure compliance with Passive Fire Safety Installation (PKK) legislation, such as the UBBL 1984 [4].

The Occupant Protection Principle emphasizes the importance of training and preparing occupants for escape and evacuation in the event of fire. This includes fire drills, the 6S methodology for housekeeping, the inspection and maintenance of fire systems, and developing procedures for unusual conditions such as large crowds or limited egress paths. Collaboration with the fire department is crucial to ensure that all occupants are aware of their responsibilities in the event of a fire as stated in the IFSS [11].

The Containment Principle stresses the need for regular maintenance to ensure that fire safety systems continue to function effectively. This includes inspecting and maintaining containment systems specified during the design and construction phases. It is essential to educate tenants about preventing unsafe DIY projects that could compromise fire protection measures, such as fire-stopping and protection of combustible walls. Proper housekeeping and adherence to the 6S methodology are also critical for maintaining containment, as outlined in IFSS [11]. A comprehensive fire safety management framework must be established for PTS facilities to assess and improve overall safety, as explained by Hassanain et al. [15]

The Extinguishment Principle requires securing fire service entrance routes, clearing fire lanes, and maintaining firefighting equipment, including dry and wet risers, water resources, and manual firefighting tools. It also involves ensuring that fire safety signage and fire service access are visible and accessible and that regular coordination with rescue and fire departments is maintained. Furthermore, emergency response training should be provided for all PTS occupants to ensure preparedness in case of a fire.

6. FINDING AND DISCUSSION

In constructing the Integrated LP and fire safety in the PTS conceptual frameworks, the SLR addresses the need for implementing Integrated Lean Project Delivery (ILPD) in the study. For instance, the SLR identified gaps in the research, and the concept of ILPD and the Fire Safety Engineering (FSE) framework leverages these gaps. By integrating these areas, this study could strengthen the arguments for the importance of LP and fire safety engineering in adopting the Prevention through Design (PtD) approach along the cycle of the case study PTS building, which is essential to be implemented from the conceptual and design, construction, occupation, refurbishment, and demolition stages.

Besides the PtD implementation, the framework also emphasizes the occupant awareness through public talks, and appointing designated fire safety officers can further enhance fire safety education. The goal of implementing school-based fire safety education programs is to increase children's fire safety knowledge and abilities, as suggested by Pooley et al. [22] and fire risk assessments should be considered such as identification of training need in fire prevention, safe escape principles, fire hazards from electrical appliances, and non-smoking rules, as discussed by Hassanain [23] for continuous improvement as part of adopting Lean Principles in the organization.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest

AUTHORS CONTRIBUTION

S. Siti Rosnah (Formal analysis; Literature review; Writing - original draft; Resources)

A. Ramli (Conceptualization; Review; Supervision)

S. Nurud Suria (Review; Editing)

M.P. Sisca (Review; Editing)

AVAILABILITY OF DATA AND MATERIALS

The data supporting this study's findings are available on request from the corresponding author

ETHICS STATEMENT

Not applicable

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