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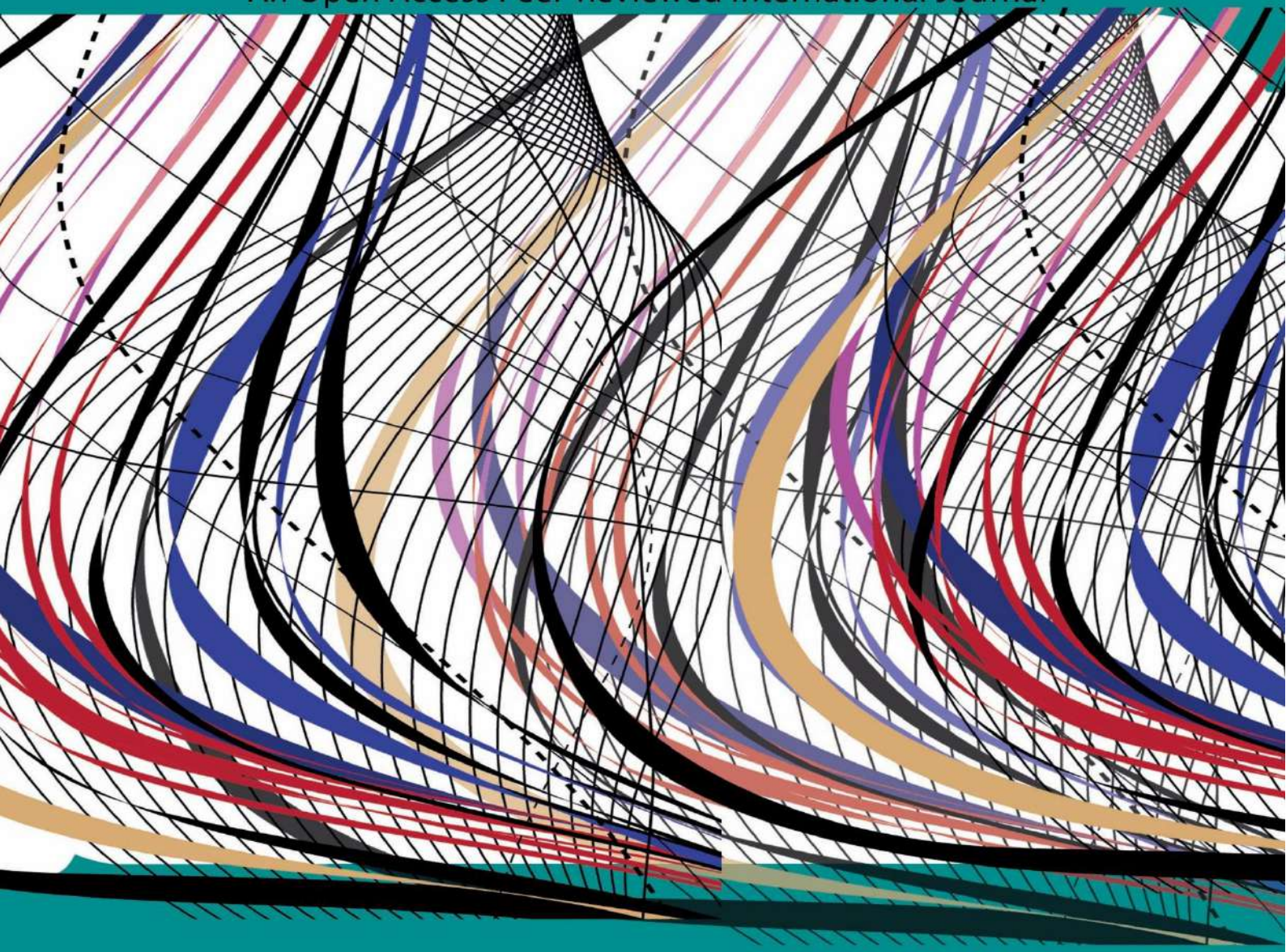

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New concept for Simulating the Cavitation Phenomenon by using Sub-grid Model for Characteristic the Fine Structures

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Abstract *— Cavitation occurs in liquid flows at the operation temperature, when the local pressure reaches values lower than the vapor pressure, inducing vaporization, this phenomenon causes some potentially negative effects such as: performance deterioration, vibration noise and cavitation erosion. This research is working on the development of new approach for simulating the cavitation phenomenon by using sub-grid model for characteristic the Fine Structures which are used for simulating the cavitation phenomenon which relay on using sub-grid model to characteristic the fine structures whose are responsible for the dissipation of turbulence energy into heat as well as for the molecular mixing, these fine structure gives the space for reactions to occur*

Keywords *— **cavitation model, eddy dissipation concept, Eulerian model for Cavitation, eddy dissipation concept***

I. INTRODUCTION

Cavitation occurs in liquid flows at the operation temperature, when the local pressure reaches values lower than the vapor pressure, inducing vaporization, this phenomenon causes some potentially negative effects such as: performance deterioration, vibration noise and cavitation erosion.

Cavitation structures exhibit various shapes and behaviors such as

- Stable or pulsating sheet cavitation
- shedding vapor clouds

There are several methods of cavitation flow modeling

- Single phase flow modelling, which is easier in terms of calculation speed and mathematical model
- Multiphase flow modelling of the mixture of liquid, vapor and possibly other undissolved gases (uncompressible flow) with cavitation
- Multiphase flow modelling of the mixture of liquid and vapors, where the bubble dynamics are calculated in accordance with the Rayleigh – Plesset equation. This method, however, is linked with the problem of determining the number of bubbles, or cavitation nuclei.

The continuum model solves Navier-Stokes (NS) equations for the fluid mixture in an Eulerian frame is quite popular for Eulerian frame with lower gas volume fractions and weak bubble oscillations, which can ignore single bubble dynamics.

Cavitation bubbles are represented by the gas volume fraction or the gas mass fraction in the Eulerian grids, which is derived based on the expression of mixture pressure or density in the equations of state (EOSs).

LE coupling formulation can be divided into two branches: one-way and two-way coupling. In one-way coupling, only the influence of the carrier phase (the carrier fluid in flow cavitation) on the dispersed phase (cavitation bubbles) is considered (under the assumption that the small bubbles move passively with the carrier fluid and that the dilute gas void fraction is rather small), so we can ignore the influence of the dispersed phase on the carrier phase. Two-way coupling increases the complexity of the nonlinear behavior of the system by considering how the dispersed bubbles influence the carrier fluid. In two-way coupling, the advection of the gas volume fraction and the pressure closure of the gas-liquid mixture are the two main challenges and still open questions

II. RESEARCH OBJECTIVE

Is the development of Eulerian model(EF) or Eulerian –Lagrange model (LE) which are used for simulating the cavitation phenomenon by using sub-grid model for cavitation phenomenon to characteristic the fine structures whose are responsible for the dissipation of turbulence energy into heat as well as for the molecular mixing, these fine structure gives the space for reactions to occur.

III. RESEARCH METHODOLOGY AND RESOURCES

A liquid at constant temperature could be subjected to a decreasing pressure, p, which falls below the saturated vapor pressure, p_v. The value of (p_v -p) is called the tension, D_p, and the magnitude at which rupture occurs is the tensile strength of the liquid, D_{pc}. The process of rupturing a liquid by decrease in pressure at roughly constant liquid temperature is often called cavitation).

IV. RESULTS AND DISCUSSION

4.1 The properties of bubble size distributions in breaking waves with the Hinze scale

In a seminal experiment on turbulent two-phase flows, Deane and Stokes (2002) performed optical measurements of bubble sizes from breaking waves in a wave flume these observations suggest that the formation of many of the bubbles larger than the Hinze scale is governed by fragmentation due to turbulent velocity fluctuations.

Define the Weber number associated with velocity fluctuations of magnitude un at a characteristic length scale l_n as

$$We_n = \rho_l . u_n^2 . l_n/\sigma = inertial\ forces/capillary\ forces$$

If ln is equal to the grid resolution Δ, and $u\Delta$ is the corresponding characteristic velocity fluctuation magnitude at this scale, then

$$We_\Delta = \rho_l . u_\Delta^2 . l_\Delta/\sigma$$

For Hinze scale lH which is assumed larger than the Kolmogorov scale corresponds to

$$We_n \sim 1$$

Then

$$l_n = l_H \sim \sigma/u_l^2\rho_l = \sigma/u_H^2\rho_l$$

As one considers length scales a little bit smaller than the Hinze scale but above the Kolmogorov scale, where the dominance of capillary-driven motion effects increasingly relative to the effects of the turbulent fluctuations. Such motion of like thin film retraction is typically associated with a Weber number of order 1 (as Taylor, 1959; Culick, 1960; Mirjalili and Mani, 2018)), which suggests that a thinning feature should be associated with a higher capillary-driven velocity uc dominate the turbulent velocity fluctuations un at the smallest scales which must have been captured by true DNS, then, requires a sufficiently small WeΔ. The dominance of inertial forces due to turbulent fluctuations over capillary forces (Wen> 1) results in the fragmentation of large features of the dispersed phase Consider an affordable LES with We$\Delta \gtrsim 1$:

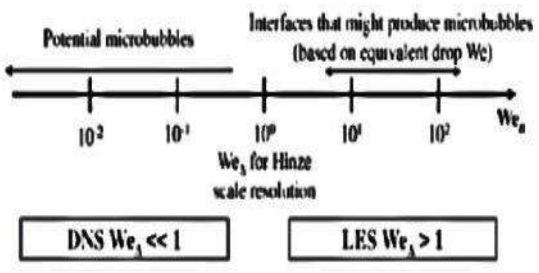


Fig.1 Schematic comparing relative length scale

If the continuous is liquid and the dispersed phase is gaseous, which yields that the microbubbles at this

sizes where are closely related to the Kolmogorov scales.

Hence Kolmogorov's hypothesis of local isotropy states that at sufficiently high Reynolds numbers, the small-scale turbulent motions

$l_{0/6} \approx l_n << l_0$

are statistically isotropic and the turbulent kinetic energy is the same everywhere κ we can calculate the ratios between the Kolmogorov scale η and large scale eddies ι_o

$$l_n = l_H \sim \sigma/u_l^2 \rho_l = \sigma/u_H^2 \rho_l$$

$$l_0 \sim \kappa^{\frac{3}{2}}/\varepsilon \ , \frac{l_0}{\eta} \sim Re_{l_0}^{3/4}, Re_\eta = 1 = \frac{u_\eta . \eta}{\nu}, \varepsilon . \eta = u_\eta^3$$

Where ε the is the average rate of dissipation, and by applied Kolmogorov Scaling typically to the inertial subrange of isotropic turbulence then

$$\left[u_n^2 \sim (\varepsilon l_n)^{2/3} = (\varepsilon l_H)^{2/3} \sim (\sigma/l_H . \rho_l)\right] \rightarrow l_H \sim (\sigma/\rho_l)^{3/5} . \varepsilon^{-2/5}$$

And for large scale ιo which in Energy containing range we conclude

$$\left[l_H \sim (\sigma/\rho_l)^{3/5} . \left(\kappa^{3/2}/l_0\right)^{-2/5}\right] \rightarrow \left[\frac{l_H}{l_0} \sim \frac{\sigma^{\frac{3}{5}}}{\rho_l^{\frac{3}{5}}} . \frac{\kappa^{\frac{-3}{5}}}{l_0^{\frac{-3}{5}} . l_0}\right] \rightarrow \frac{l_H}{l_0} \sim We^{\frac{-3}{5}}$$

Then one can write

$$\left[l_H \sim l_0 . We^{\frac{-3}{5}}\right] \leftrightarrow \left[l_H \sim \eta . Re^{\frac{3}{4}} . We^{\frac{-3}{5}}\right]$$

As shown by Garrettel at. (2000) one could extend the interial subrange argument to the bubble size distribution directly, so for a bubble to be broken by the turbulent eddy its size must be equal or smaller than eddy size and at this scale weber number must be greater than 1, So the hydrodynamic pressure fluctuations $\rho_l . u_n^2$ must be larger than capillary pressure σ/r_0 . As explained by Moore & Saffman (1975) the circulation of a shear-layer eddy can be estimated to be $\Gamma = \Delta u . \lambda$, where Δu is the velocity difference a cross the share layer and λ is the distance between neighboring eddies then in simple way similar to the "Rankine vortex", considering the constant pressure inside the cavitation bubble, the pressure distributions of a cavitation vortex are as follows

$$P = P_V, \qquad (r \le r_0)$$
$$P = P_\infty - \frac{\rho \Gamma^2}{8\pi^2} . \frac{1}{r^2}, (r \ge r_0)$$

Here, P_V is assumed to be the vapor pressure at the liquid temperature, P_∞ is the pressure of the surroundings, ρ is the density, Γ is the circulation of the free vortex, and r_0 is the radius of the central core. The central core of the cavitation vortex is regarded as the cavitation bubble, the pressure at the bubble boundary $r = r_0$ can be calculated as

$$P_{bubble-boundray} = P_V = P_\infty - \frac{\rho \Gamma^2}{8\pi^2} . \frac{1}{{r_0}^2}$$

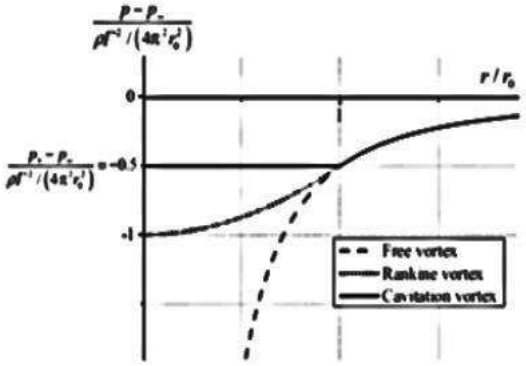


Fig. 2: shows the pressure distributions of various types of vortices

4.2 *MODELLING THE FINE STRUCTURES AND THE INTERSTRUCTURAL MIXING*

The energy spectrum characterizes the turbulent kinetic energy distribution as a function of length scale. The energy distribution at the largest length scales is generally dictated by the flow geometry and mean flow speed. In contrast, the smallest length scales are many orders of magnitude smaller than the largest scales and hence are isotropic in nature. In between, we can describe an inertial subrange bounded above by the integral scale and below by the Kolmogorov microscale

In this range, the spectrum will only be a function of the length scale and the dissipation rate, note fig.3:

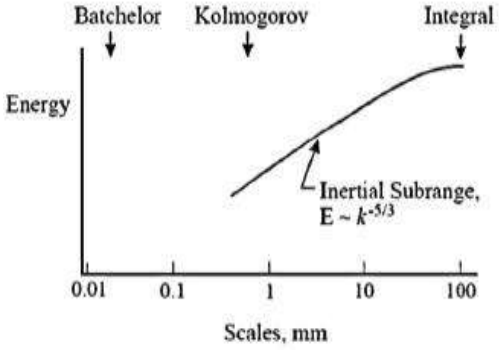


Fig.3: Typical turbulence energy spectrum, with length scales

So the first structure level is characterized by a turbulence velocity, u` , a length scale, L` , and vortices, or characteristic stain rate ω`.

The rate of dissipation $\varepsilon`$ for this level is the sum of two parts which are the first part which is directly dissipated into heat and the second one is the part of energy which transfer from the first level to the second level so,

$$\varepsilon' = \zeta^2 \left[12 \frac{u'}{l'} . u''^2 + 15 . \nu . \left(\frac{u'}{l'} \right)^2 \right]$$

the part of energy which transfer from the first level to the second level is

$$\left(\zeta^2 . 12 \frac{u'}{l'} . u''^2 \right)$$

Similarly this part of energy from the second directly dissipated into heat at the second level as

$$\left(q'' = \zeta^2 . 15 . \nu . (u''/l'')^2 \right)$$

and part of energy transfer to the third level as:

$$\left(w'' = \zeta^2 . 12 . \frac{u''}{l''} . u'''^2 \right)$$

So the model for turbulent is cleared by fig.4

This sequence of turbulence continue down to a level where all the produced mechanical energy transferred is dissipated into heat. This is the fine structure level characterized by, u*, L*, and ω*.

The mechanical energy transferred to the fine structure is

$$\left(w^* = \zeta^2 . 12 . \frac{u^*}{l^*} . u^{*2} \right)$$

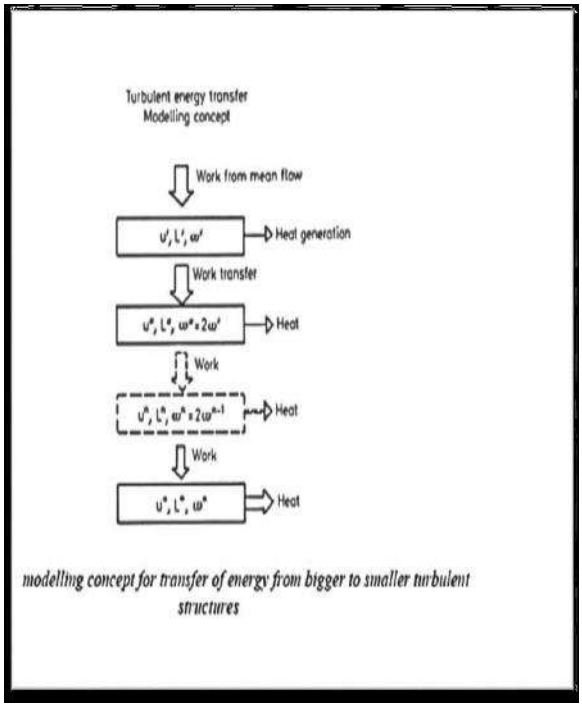
and the dissipation into heat is

$$\left(q^* = \zeta^2 . 15 . \nu . (u^*/l^*)^2 \right)$$

It was shown to be in accordance with Kolmogorov's theory for its 5/3 law. We have the fine structure level characterized by, u*, L*, and ω* in inertial subring. The constant $\zeta^2 = 1$ for the energy spectrum of Kolmogorov microscale, thus for energy spectrum of the inertial subrange energy $\zeta^2 \ll 1$

by putting $\zeta = 0.18$ We have the fine structure level characterized by, u*, L*, and ω* in inertial subrang. The Re^* for this fine structure level equal to

$$\left(u^* . \frac{l^*}{\nu} = \frac{\left(\left(1.75 (\varepsilon . \nu)^{\frac{1}{4}} \right) \left(\frac{1.43 \nu^{\frac{3}{4}}}{\varepsilon^{\frac{1}{4}}} \right) \right)}{\nu} = 2.5 \right)$$



modelling concept for transfer of energy from bigger to smaller turbulent structures

Fig.4: Modeling concept for transfer of energy from bigger to smaller structure

The microscale processes concentrated in isolated regions in nearly constant energy regions where the turbulence kinetic energy can be characterized by u'2. So the mass fraction occupied by the fine structure regions can be expressed by

$$\left(\gamma^* = \left(\frac{u^*}{u'} \right)^2 \right)$$

but the fine structures whose are responsible on molecular mixing as well as dissipation of turbulence energy into heat are of the same magnitude as Kolmogorov microscales or smaller, which result in

for these fine structures are very localization fashion and its linear dimensions are considerably larger than the fine structures therein, It is assumed that these structures consist typically of large thin vortex sheets, ribbons of vorticity or vortex tubes of random extension folded or tangled in the flow

The N^3 wavenumbers represented are

$$\vec{\kappa} = \kappa_0 \vec{n} = \kappa_0 \left(e_1 n_1 + e_2 n_2 + e_3 n_3\right),$$

For integer values of n_i between $-(1/2)N+1$ and $(1/2)N$

The largest wavenumber represented is

$$\kappa_{\max} = \frac{1}{2} N \kappa_0 = \frac{\pi N}{\mathcal{L}},$$

This spectral representation is equivalent to representing

$$\Delta x = \frac{\pi}{\kappa_{\max}} \Rightarrow \frac{\Delta x}{\eta} = \frac{\pi}{1.5} \approx 2.1.$$

The resolution of the smallest, dissipative motions, characterized by the Kolmogorov scale η, requires a sufficiently small grid spacing as clear in fig.5:

$k_{max}\,\eta \geq 1.5$

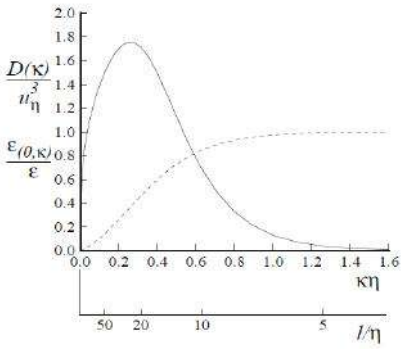


Fig.5: Dissipation spectrum (solid line) and cumulative dissipation (dashed line): $\ell = 2\pi/\kappa$ is the wavelength corresponding to wavenumber

The two spatial resolution requirements determine the necessary number of Fourier modes (or grid modes)

$$N = 2\frac{\kappa_{\max}}{\kappa_0} = 2\frac{\kappa_{\max}}{\kappa_0 L_{11}}\left(\frac{L_{11}}{L}\right)\left(\frac{L}{\eta}\right) = \frac{12}{\pi}\left(\frac{L_{11}}{L}\right)\left(\frac{L}{\eta}\right)$$

In this equation L is the scale based in the turbulent kinetic energy and the dissipation

$$L \equiv k^{3/2}/\varepsilon.$$

From experiments, it is known that

$$\left(\frac{L_{11}}{L}\right) \approx 0.43,$$

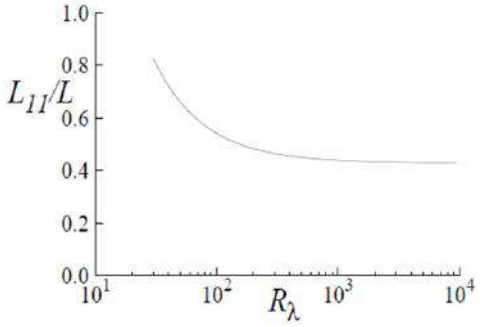


Fig .6 Show the ratio of L_{11} and L ,

The previous equation becomes,

$$\left(N = \frac{12}{\pi}(0.43)\frac{L_0}{\eta},\ \frac{\eta}{L_0} = Re_L^{-3/4}, R_\lambda = \left(\frac{20}{3}Re_L\right)^{1/2}\right) \rightarrow$$

$$\left(N = 1.6\,Re_L^{3/4} = 0.4\,Re_\lambda^{3/2} \rightarrow N^3 = 4.4\,Re_L^{9/4} = 0.06Re_\lambda^{9/2}\right)$$

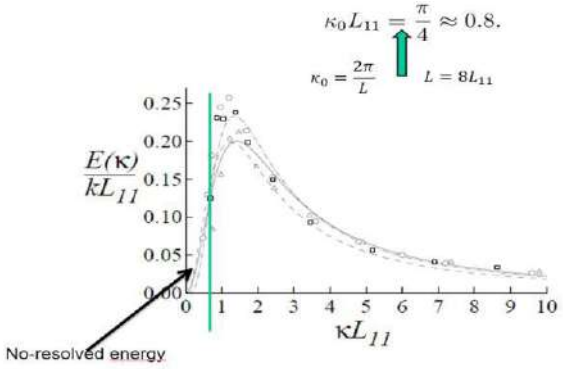


Fig.7: Show the resolved turbulent energy

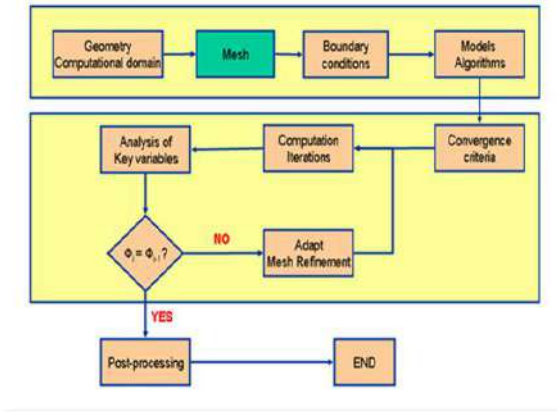
For the advance of the solution in time to be accurate, it is necessary that a fluid particle move only a fraction of the grid spacing Δx in a time Δt. In practice the limit is given by the Courant-Friedrichs-Lewis (CFL) number

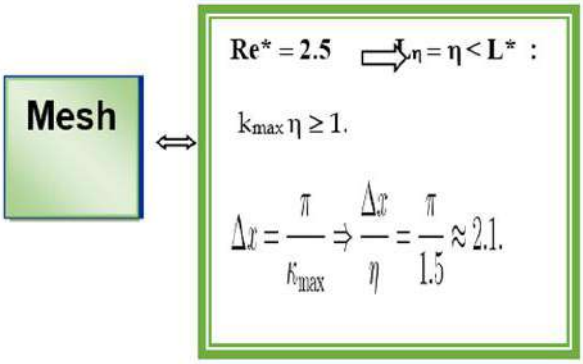
$$\frac{k^{1/2}\Delta t}{\Delta x} = \frac{1}{20}.$$

The duration of a simulation is tipically at least four times the turbulence time scale, $\tau = k/\varepsilon$, so the number of time steps required is

$$M = \frac{4\tau}{\Delta t} = 80\frac{L}{\Delta x} = \frac{120}{\pi}\frac{L}{\eta} \approx 9.2R_\lambda^{3/2}.$$

In result we can modify some steps in this diagram for CFD simulation:





V. CONCLUSION

By modeling the molecular mixing processes in spite of modelling the turbulence chemical kinetic interaction in similar way of the applying of EDDY DISSIPTION CONCEPT the DNS frame simulation procedure will catch the features of some reactor which have cavitation phenomena within the mixing and reaction process and this is new at all for these cavitation models.

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Asset Management Maturity and Lifecycle Practices based on Stakeholders' Feedback

Dr. Josef Z. Nacino

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Abstract *— This research investigates the maturity and performance of asset management systems and lifecycle practices in private Higher Education Institutions (HEIs) in Cabanatuan City, Philippines, using stakeholders' feedback. In particular, it evaluates how institutional policies, data and information management, and monitoring of performance contribute towards the application of the Asset Lifecycle Management (ALM) Model. Employing a descriptive research design, information was collected via survey questionnaires administered to 120 respondents (heads, and faculty and staff). Findings indicate that the asset management system in terms of strategy and policy is very satisfactory, signifying well-defined and established guidelines. Data and information management, as well as performance management, are merely satisfactory, hinting at improvement in data integration, training, and ongoing performance assessment. The ALM model itself fares no better, being rated as satisfactory with standardized lifecycle assessment processes in place, but with little sustainability integration and strategic alignment. The findings go a long way to emphasize the need to institutionalize end-to-end asset management strategies that leverage data analytics, stakeholder engagement, and long-term planning. The research offers empirical evidence that can be used to advise policy changes and capacity development efforts aimed at enhancing asset management and sustainability within higher education institutions.*

Keywords *— **ALM model, asset management maturity, lifecycle practices, private HEIs, stakeholders***

I. INTRODUCTION

Effective physical asset management in private HEIs is more and more vital as they aim to maximize resources, achieve sustainability, and harmonize their operations with strategic objectives (Chen et al., 2020). For this purpose, the Asset Lifecycle Management (ALM) Model (Roda, Macchi & Albanese, 2020) has become a crucial model for managing assets across their whole life cycle, from acquisition to use and maintenance to eventual decommissioning (Oh & Kim, 2020). Nevertheless, there is limited empirical evidence assessing comprehensively how ALM is supported and practiced in policy, data handling, and performance areas within the HEI context. This study is proposed to fill that gap.

This study sought to measure the existing practice of asset lifecycle practice in private HEIs by surveying three related components: institutional policy and strategy, data and information management, and performance management. These aspects are likely to have a major effect on the extent to which the ALM model is implemented at various functional levels within the organization (Kaewunruen, Sresakoolchai & Zhou, 2020). Knowing how these dimensions interact will better describe asset lifecycle effectiveness in education.

Initial observations indicate that even if most institutions have basic systems in place, the level of integration, stakeholder engagement, and strategic linkage will differ significantly. In addition, there has been an increasing awareness of enhancing sustainability practices, risk mitigation strategies, and

data analytics in decision-making regarding assets. These areas were scrutinized in the research to explore the strengths and areas of improvement in ALM implementation (Wekwete, Kufakunesu & van Zyl, 2023).

This research utilized quantitative data analysis to measure perceptions and practices across institutional heads, faculty, and staff, focusing on their experiences and evaluations of asset management strategies. The insights gathered are expected to contribute to a clearer understanding of how ALM is being applied in real-world HEI settings and what systemic or operational improvements might be necessary to support its full adoption.

This study specifically addressed and answered the following questions:

1. How may the asset management (physical assets/facilities) of the HEIs be described in terms of the Asset Management Maturity Model?

2. How may the asset lifecycle management in the HEIs be described by the respondents?

II. METHODOLOGY

A descriptive research design was used in this study. Posinasetti (2014) stated that a descriptive study is one in which information is collected without changing the environment (i.e., nothing is manipulated). It is used to obtain information concerning the status of the phenomena to describe "what exists" to variables or conditions in a situation. The methods involved range from the survey, which describes the status quo, to the correlation study, which investigates the relationship between variables, to developmental studies that seek to determine changes over time.

The respondents of the study are from private higher education institutions (HEIs) within Cabanatuan City, Philippines. The total number of respondents is 120, with 30 people from the group of the Heads and 90 from the faculty and staff.

This study used a survey questionnaire intended for the heads, faculty, and staff of selected private HEIs in Cabanatuan City. The questionnaire is divided into two parts. Part 1 of the questionnaire is composed of items on the asset management maturity level indicators (policy and strategy, data and information management, and performance management), and Part 2 is about the asset lifecycle management model. The instrument was content validated by 5 experts in the field, while the reliability was established using Cronbach's alpha with a coefficient of 0.856.

Appropriate statistical tools were used to treat the data gathered. The study covers one academic year.

III. RESULTS AND DISCUSSION

1. Asset Management System for Physical Assets/Facilities

Table 1. *Asset Management System for Physical Assets/Facilities in Terms of Policy and Strategy*

No.	Policy and Strategy	Heads		Faculty and staff		Combined	
		W.m	V.D	W.m	V.D	W.m	V.D
1.	Have a clear, comprehensive, and easily understandable guidelines outlining the acceptable use of assets within the institution, covers everything from procurement procedures to disposal policies.	3.43	s.a/v.s	**3.53**	**s.a/v.s**	**3.48**	**s.a/v.s**

2.	Implement a system for accurately identifying, tracking, and inventorying all institutional assets.	3.27	s.a/v.s	3.40	s.a/v.s	3.33	s.a/v.s	
3.	Have defined procedures for acquiring new assets, including approval processes, budgeting considerations, and vendor selection criteria. Emphasize transparency, accountability, and adherence to budgetary constraints.	**3.47**	**s.a/v.s**	3.50	s.a/v.s	**3.48**	**s.a/v.s**	
4.	Have an established asset management objectives aligned with the institution's strategic goals.	3.40	s.a/v.s	3.40	s.a/v.s	3.40	s.a/v.s	
5.	Have designated resources (human, financial, technological) allocated specifically for the implementation of asset management strategies.	3.40	s.a/v.s	3.43	s.a/v.s	3.42	s.a/v.s	
6.	The asset management policy of the institution is communicated effectively to all relevant stakeholders, including staff, faculty, and administration.	3.33	s.a/v.s	3.44	s.a/v.s	3.39	s.a/v.s	
7.	Conducts regular reviews and Assessments of asset management practices to ensure alignment with institutional objectives.	3.33	s.a/v.s	3.46	s.a/v.s	3.39	s.a/v.s	
8.	The asset management objective within the institution are SMART (Specific, Measurable, Achievable, Relevant, Time-bound).	3.30	s.a/v.s	3.34	s.a/v.s	3.32	s.a/v.s	
9.	Actively engages stakeholders in the development and review of asset management policies and strategies.	**3.17**	**a/s**	**3.31**	**a/s**	**3.24**	**a/s**	
10.	The asset management strategy within the institution is aligned with industry standards and best practices.	3.37	s.a/v.s	3.40	s.a/v.s	3.38	s.a/v.s	
	Overall Weighted Mean	3.35	s.a/v.s	3.42	s.a/v.s	3.38	s.a/v.s	

Legend: 3.25-4.00 strongly agree (s.a)/very satisfactory (v.s) 2.50-3.24 agree (a)/satisfactory (s) 1.75-2.49 moderately agree (m.a) 1.00-1.74 disagree (d)

Table 1 outlines the asset management system of private HEIs for physical assets/facilities in terms of policy and strategy. The overall weighted mean for the Asset Management System of private HEIs for physical assets/facilities in terms of policy and strategy is 3.35, 3.42, and 3.38, respectively, which is categorized as "strongly agree/very satisfactory." This information indicates that there is an established policy and strategy within the private HEIs.

From data collected from the heads of Higher Education Institutions (HEIs) on their Asset Management System for physical assets and facilities, some important insights surface on policy and strategy implementation. The most highly rated item, 3. "Have defined procedures for acquiring new assets, including approval processes, budgeting considerations, and vendor selection criteria." Highlight transparency, accountability, and staying within budget limitations." with a weighted mean of 3.47 and labeled by as "strongly agree/very satisfactory," addresses the presence of well-defined procedures for procuring new assets. These encompass clear approval mechanisms, budgetary considerations, and vendor selection criteria. The highlighting of transparency, accountability, and staying within budgetary limitations suggests a solid system in place among these HEIs. This high rating suggests that institutions prioritize structured and accountable processes for asset acquisition, ensuring that new investments align with strategic goals and financial plans (Li, 2023).

For staff and faculty, Item 1 received the most highly weighted mean of 3.53 and was labeled as "strongly agree/very satisfactory," referring to the availability of clear, detailed guidelines specifying the acceptable use of assets in the institution. Such guidelines cover procurement practices to disposal policy. This highly rated response suggests that staff and faculty see the existence of well-defined and easily comprehensible policies that strictly guide asset use and management. Clear policies ensure consistency, accountability, and conformity with regulatory requirements throughout the institution (Abbott & Snidal, 2021). From the aggregate data collected from the heads, faculty, and staff for the Asset Management System of Higher Education Institutions (HEIs) for physical assets and facilities, certain important findings are made in terms of policy and strategy implementation.

Two of the items were rated the highest by the respondents, both with a weighted mean of 3.48 and tagged as "strongly agree/very satisfactory." The two items are having clear and complete guidelines on the allowable use of assets in the institution (Item 1) and established procedures on procuring new assets, stressing transparency, accountability, and strict compliance with budgetary limits (Item 3). High ratings here signal respondent agreement that HEIs have strong systems for managing asset use, procurement procedures, and financial management. Distinct instructions and organized procedures are essential to facilitate operational effectiveness, ensure compliance with laws and regulations, and maximize resource utilization across the institution (PURBA & Farah, 2021).

Table 2. Asset Management System for Physical Assets/Facilities in Terms of Data and Information Management

No.	**Data and Information Management**	Heads		Faculty	Combined and staff		
		W.m	V.D	W.m	V.D	W.m	V.D
1.	Establish a centralized data repository to store information about all institutional assets.	3.17	a/s	3.21	a/s	3.19	a/s
2.	There is a define standardized	3.20	a/s	3.24	a/s	3.22	a/s

	format and protocol for recording asset data to ensure consistency and compatibility across different departments and systems within the institution.						
3.	Maintain a comprehensive inventory of all institutional assets, including equipment, facilities, technology resources, intellectual property, and research materials.	**3.23**	**s.a/v.s**	**3.39**	**s.a/v.s**	**3.31**	**s.a/v.s**
4.	Implement processes for regularly updating and maintaining asset data to ensure accuracy and relevance over time.	3.13	a/s	3.22	a/s	3.18	a/s
5.	Implement robust data security measures to protect sensitive asset information from unauthorized access, disclosure, or tampering. This includes encryption, access controls, data back-ups, and compliance with relevant data protection regulations.	3.10	a/s	3.20	a/s	3.15	a/s
6.	Integrate asset data management processes with dedicated asset management systems or enterprise resource planning (ERP) platforms.	**2.97**	**a/s**	3.13	a/s	3.05	a/s
7.	Provide training and support to personnel responsible for managing asset data, including administrators, facilities staff, IT professionals, and researchers.	**2.97**	**a/s**	**3.09**	**a/s**	**3.03**	**a/s**
8.	Establish a data governance framework to define roles, responsibilities, and accountability for asset datamanagement within the institution.	3.03	a/s	3.10	a/s	3.07	a/s
9.	Leverage data analytics tools and reporting capabilities to gain	3.13	a/s	3.14	a/s	3.14	a/s

	insights into asset utilization, performance, and lifecycle management.						
10.	continuously monitor and evaluate The effectiveness of asset data management practices within the institution.	3.20	s.a/v.s	3.30	s.a/v.s	3.25	s.a/v.s
	Overall Weighted Mean	**3.11**	a/s	**3.20**	a/s	**3.16**	a/s

Legend: 3.25-4.00 strongly agree (s.a)/very satisfactory (v.s) 2.50-3.24 agree (a)/satisfactory (s) 1.75-2.49 moderately agree (m.a) 1.00-1.74 disagree (d)

Table 2. presents the practices of the private HEIs with their Asset Management System for physical assets/facilities in terms of data and information management. The overall weighted mean for the Asset Management System of private HEIs for physical assets/facilities in terms of data and information management is 3.11, 3.20, and 3.16, respectively, which is categorized as "agree/satisfactory." This indicates overall satisfaction with the system's performance; it also acknowledges potential areas for enhancement. Institutions may consider leveraging this baseline assessment to identify specific areas where improvements could further streamline asset management processes, enhance data accuracy, or improve the integration of information across departments.

Drawing from the information collected from heads of Higher Education Institutions (HEIs) about their Asset Management System for physical assets and facilities, with an eye towards data and information management, certain important findings and observations could be noted. The most highly rated item, 3, with a weighted mean of 3.23 and identified as "strongly agree/very satisfactory," maintains a complete inventory of all institutional assets. These include equipment, facilities, technology resources, intellectual property, and research material.

According to data collected from the faculty and staff members on the Asset Management System of Higher Education Institutions (HEIs) for physical assets and facilities and on data and information management, there are a number of important conclusions that can be derived from the results. The top-ranked item, 3, which was rated at 3.39 with the descriptor "strongly agree/very satisfactory," deals with having an extensive inventory of all institutional assets.

As indicated by the collective data compiled from heads, staff, and faculty, the highest rated is also item 3, with a weighted mean of 3.31 and termed "strongly agree/very satisfactory." This high rating indicates an agreement by faculty and staff regarding the significance of possession of accurate and current records of all assets in the institution. An exhaustive inventory is essential for accurate asset tracking, maintenance planning, budgeting, and compliance with regulatory requirements (Dinçkol, Ozcan & Zachariadis, 2023).

Table 3. Asset Management System for Physical Assets/Facilities in Terms of Performance Management

No.	**Performance Management**	Heads		Faculty and staff		Combined	
		W.m	V.D	W.m	V.D	W.m	V.D
1.	Have key performance indicators (KPIs) used to measure the effect-	**3.37**	**s.a/v.s**	3.29	s.a/v.s	3.33	s.a/v.s

	iveness of asset management practices.						
2.	Have a continuous improvement initiatives are implemented based on asset management performance evaluations.	3.17	a/s	3.24	a/s	3.21	a/s
3.	Have a regular audit or assess- 3.10 ments conducted to ensure compliance with asset management policies and procedures.	a/s	3.24	a/s	3.17	a/s	
4.	Have an asset management performance metrics communicated effectively to relevant stakeholders within the institution.	3.17	a/s	3.21	a/s	3.19	a/s
5.	Actively seeks feedback from users and stakeholders to improve asset management practices.	**2.97**	**a/s**	3.17	a/s	**3.07**	**a/s**
6.	Have a process in place to address and rectify identified deficiencies or gaps in asset management performance.	3.13	a/s	**3.13**	**a/s**	3.13	a/s
7.	Have an asset management performance reports used to inform strategic decision-making within the institution.	3.33	s.a/v.s	**3.34**	**s.a/v.s**	**3.34**	**s.a/v.s**
8.	Actively benchmarks its asset 3.20 Management performance against industry standards or best practices.	a/s	3.23	a/s	3.22	a/s	
9.	have an asset management performance evaluation conducted regularly and systematically.	3.17	a/s	3.27	a/s	3.22	a/s
10.	have the opportunities for training and development related to asset management performance improvement provided to relevant staff members	3.20	a/s	3.26	a/s	3.23	a/s
	Overall Weighted Mean	**3.18**	a/s	**3.24**	a/s	**3.21**	a/s

Legend: 3.25-4.00 strongly agree (s.a)/very satisfactory (v.s) 2.50-3.24 agree (a)/satisfactory (s) 1.75-2.49 moderately agree (m.a) 1.00-1.74 disagree (d)

Table 3 presents the practices of private HEIs with their Asset Management System for physical assets/facilities in terms of performance management. The overall weighted mean for the Asset Management System of private HEIs for physical assets/facilities in terms of performance management is 3.18, 3.24, and 3.21, respectively, which is categorized as "agree/satisfactory." Institutions may use this baseline assessment to identify opportunities to enhance performance monitoring processes, potentially by implementing more advanced monitoring technologies or refining performance indicators to better align with institutional goals and benchmarks. It also underscores the importance of ongoing evaluation and refinement to continuously enhance asset performance, optimize resource utilization, and support the institution's overall mission and objectives effectively.

The top-rated item for heads is Item 1, with a weighted mean of 3.37 and described as "strongly agree/very satisfactory," relating to having key performance indicators (KPIs) used to measure the effectiveness of asset management practices. This shows an overwhelming consensus among heads that HEIs use measurable parameters to assess the extent to which asset management practices are working. KPIs are important to enable objective evaluation, to realize areas for improvement, and to align asset management actions with institutional priorities and goals (Budihardjo et al., 2021). The most highly rated item by faculty and staff, with an average weighted response of 3.34 and characterized as "strongly agree/very satisfactory," is in relation to the utilization of asset management performance reports to guide strategic decision-making at the institution (Item 7).

This reflects a strong degree of consensus and favorable outlook in connection with the application of asset management performance reports in strategic decision-making among private Higher Education Institutions (HEIs). This rating implies that staff and faculty members assume that these reports are vital in influencing and shaping strategic decisions pertaining to asset management. For both heads and faculty and staff, item 7, with a weighted mean of 3.34 and "strongly agree/very satisfactory," is defined as asset management performance reports being utilized to guide decision-making at the institution.

This shows a high level of agreement among the respondents that HEIs use formal reports to measure asset management effectiveness. These formal reports become imperative in offering actionable information, highlighting trends, and aiding decision-making processes in resource planning and operations enhancement (Tortorella, 2019).

2. Asset Lifecycle Management Model (ALM) for Physical Assets/Facilities

Table 4. Asset Lifecycle Management Model (ALM) for Physical Assets/Facilities

No.	**ALM**	Heads		Faculty and staff		Combined	
		W.m	V.D	W.m	V.D	W.m	V.D
1.	Utilizes standardized methodologies or frameworks for assessing the lifecycle stages of assets (e.g., acquisition, utilization, maintenance, disposal).	**3.47**	**s.a/v.s**	**3.42**	**s.a/v.s**	**3.44**	**s.a/v.s**

2.	Have an established procedure for determining the optimal timing of asset replacement or disposal based on lifecycle considerations.	3.20	a/s	3.26	a/s	3.23	a/s	
3.	Incorporates sustainability principles into asset lifecycle management practices, such as promoting reuse, recycling, or refurbishment.	3.13	a/s	3.26	a/s	3.19	a/s	
4.	Asset lifecycle management plans within our institution consider the total cost of ownership, including acquisition, maintenance, and disposal costs.	3.10	a/s	3.18	a/s	3.14	a/s	
5.	Employs risk management techniques to mitigate potential risks associated with asset lifecycle decisions (e.g., technological obsolescence, market fluctuations).	3.00	a/s	**3.02**	**a/s**	3.01	a/s	
6.	Have a documented process for evaluating the performance and effectiveness of asset lifecycle management strategies within the institution.	3.07	a/s	3.19	a/s	3.13	a/s	
7.	Collaborates with external partners or vendors to optimize asset lifecycle management practices (e.g., through maintenance contracts, disposal services).	**2.93**	**a/s**	3.04	a/s	2.99	a/s	
8.	Asset lifecycle management decisions within the institution are based on comprehensive analyses of asset performance, condition, and future needs.	**2.93**	**a/s**	3.03	a/s	**2.98**	**a/s**	
9.	Asset lifecycle planning is Integrated into our institution's strategic planning processes.	3.00	a/s	3.12	a/s	3.06	a/s	

10.	Regularly assesses the condition of assets to inform lifecycle decisions.	3.23	a/s	3.14	a/s	3.19	a/s
	Overall Weighted Mean	**3.11**	**a/s**	**3.17**	**a/s**	**3.14**	**a/s**

Legend: 3.25-4.00 strongly agree (s.a)/very satisfactory (v.s) 2.50-3.24 agree (a)/satisfactory (s) 1.75-2.49 moderately agree (m.a) 1.00-1.74 disagree (d)

Table 4. outlines the Asset Lifecycle Management Model of private HEIs for physical assets/facilities. The overall weighted mean for the Asset Lifecycle Management Model of private HEIs for physical assets/facilities is 3.11, 3.17, and 3.14, respectively, which is categorized as "agree/satisfactory." It indicates that heads and faculty and staff perceive the Asset Lifecycle Management Model as effectively managing the lifecycle of physical assets—from acquisition or construction through maintenance, utilization, and eventual disposal or replacement. It suggests that the model is adequately structured to ensure assets are managed in a way that supports operational needs, regulatory compliance, and institutional objectives. Institutions may use this evaluation as a baseline to identify opportunities for enhancing asset lifecycle processes, such as implementing more efficient maintenance strategies, integrating sustainability considerations into asset management practices, or leveraging technology to streamline asset tracking and management (Al-Shaikhli, 2023).

The top-ranked item among heads, faculty and staff, and combined responses of heads and faculty with a weighted mean of 3.47, 3.42, and 3.44, labeled as "strongly agree/very satisfactory," refers to using standardized methodologies or frameworks for evaluating the asset lifecycle stages (Item 1). This reflects a high agreement between heads and faculty and staff that HEIs utilize structured methods to review asset lifecycles, from acquisition, utilization, and maintenance to disposal stages. Standardized methodologies give a systematic method of handling assets cost-effectively, maximizing the allocation of resources, and preventing non-compliance with regulatory standards (Yakubu & Bunyaminu, 2023).

Table 5. *Overall Tables for the Asset Management System Maturity Level and Asset Lifecycle Management Model*

	Heads		**Faculty and Staff**		**Combined**	
Indicators	O.W.M	V.D	O.W.M	V.D	O.W.M	V.D
Policy and strategy	3.35	S.A/V.S	3.42	S.A/V.S	**3.38**	S.A/V.S
Data and Information Management	3.11	A/S	3.20	A/S	**3.16**	A/S
Performance Management	3.18	A/S	3.24	A/S	**3.21**	A/S
Asset Lifecycle Management	3.11	A/S	3.17	A/S	**3.14**	A/S

Legend: 3.25-4.00 strongly agree (s.a)/very satisfactory (v.s) 2.50-3.24 agree (a)/satisfactory (s) 1.75-2.49 moderately agree (m.a) 1.00-1.74 disagree (d)

Table 5 presents the overall weighted mean of the asset management maturity model and the asset management lifecycle model in terms of policy and strategy with a combined weighted mean of 3.38 and is described as "strongly agree/very satisfactory." Stakeholders are highly satisfied with how policy and strategic frameworks are defined and implemented in asset management. Conversely, data and information management, performance management, and asset lifecycle management got a combined overall weighted mean of 3.16, 3.21, and 3.14, which is categorized as "agree/satisfactory." This suggests

that while stakeholders find data management, performance measurement, and asset lifecycle management satisfactory, there may be room for improvement or refinement in these areas to achieve higher levels of satisfaction and efficiency (Ferreira et al., 2020).

IV. CONCLUSIONS

The following conclusions are derived based on the findings of the study:

1. The Asset Management System in terms of Policy and Strategy is perceived as very satisfactory, highlighting the presence of clear, comprehensive, and well-implemented guidelines across private HEIs.

2. The Asset Management System in terms of Data and Information Management is rated satisfactory, indicating the need for improved data integration, training, and security despite generally effective asset inventory practices.

3. The Asset Management System, in terms of Performance Management is assessed as satisfactory, with structured performance reporting recognized as valuable for strategic decision-making, though continuous improvement processes could be strengthened.

4. The Asset Lifecycle Management Model is also deemed satisfactory, with strong adherence to standardized lifecycle assessment methods, yet opportunities remain for enhancing sustainability practices and strategic integration.

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Optimization and modeling of a solar air system for residential thermal comfort in tropical climate

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Abstract *— This study presents a solar air system designed for heating, cooling, and air conditioning in buildings. The system uses a flat-plate solar collector and a photovoltaic panel to capture solar energy. Heated air circulates through a thermal chamber to maintain indoor comfort. An electric resistor and a cold-water circuit provide backup heating or cooling. The thermal modeling is based on analytical equations and an energy signature method. Simulations are performed using Matlab with local data from Antananarivo. The system operates using a thermodynamic process similar to the Carnot cycle. Results show variable thermal efficiency throughout the day, with a performance coefficient above 3. This system ensures thermal comfort while reducing fossil energy consumption. It fits well with tropical climate conditions and the needs of low-income households.*

Keywords *— Air collector, Building thermal comfort, Photovoltaic system, Solar heating, Thermal modeling*

I. INTRODUCTION

Since the 1950s [1], global energy consumption has increased significantly. It rose from 2 Gtep/year to about 10 Gtep/year by 2000. This rise follows the evolution of human societies. The global population is growing rapidly. Urbanization and economic development are expanding. These trends drive increasing energy demand, especially in developing countries. In 2009 [2], more than 80% of consumed energy came from fossil fuels. Oil, natural gas, coal, and uranium still dominate the global energy mix. These energy sources have major environmental impacts. They release large amounts of carbon dioxide. They also emit methane during extraction. These gases worsen the greenhouse effect and global warming. In response, renewable energy provides a sustainable alternative. It can meet demand while protecting the environment.

Renewable energies come from continuous natural phenomena and are inexhaustible in the long term. They produce little or no pollution and are environmentally friendly. Their use is growing rapidly due to climate concerns and the rising cost of fossil fuels. This study focuses on solar energy, a clean, abundant, and easily exploitable source. The objective is to assess solar potential for applications such as domestic heating, cooling, and air conditioning, [3].

This work addresses challenges related to the use of solar thermal energy, a free and abundant resource, in an active system. The goal is to maximize its efficiency using thermal balance principles and analytical sizing methods.

The study begins with an overview of astronomical foundations of solar radiation and the key characteristics of the solar resource that affect system performance. It continues with a description of core solar technologies and components of a solar air system. Modeling, simulations, and sizing calculations are performed to assess the performance of the experimental setup. The analysis uses a global thermal balance approach and rigorous mathematical methods. Practical applications are then conducted in real conditions to test system efficiency over a defined period, and the results are processed and interpreted using Matlab software.

II. MODELING AND THERMAL ANALYSIS OF SOLAR ENERGY SYSTEMS

1. Solar parameters for energy system optimization

The Sun is the primary energy source for Earth. It is located approximately 150 million kilometers away and emits radiation similar to a black body at 5800 K. This electromagnetic radiation reaches the Earth in about 8 minutes, with 98% of its energy concentrated between 0.25 and 3 µm. Solar radiation enables life, influences the climate, and drives weather phenomena, [4].

Earth orbits the Sun in a slightly eccentric elliptical path. Its average orbital speed is about 30 km/s, [5]. The tilt of Earth's rotation axis causes seasonal changes. This tilt is responsible for the annual variation of solar declination. The Sun's position in the sky depends on several astronomical parameters: latitude, longitude, declination, hour angle, solar altitude, azimuth, and zenith distance.

These parameters determine the Sun's apparent trajectory and are crucial for optimizing solar collector orientation. The declination varies between ±23.27° depending on the season. The hour angle defines the Sun's position relative to solar noon. Solar altitude measures the Sun's elevation above the horizon. Azimuth indicates its horizontal direction. Zenith distance is the complement of the altitude angle.

2. Solar time and local energy applications

True Solar Time (TST) depends on Earth's rotation on its axis. It is defined by the solar hour angle at a given moment. The sun reaches its zenith at solar noon. TST varies due to the Equation of Time (ET), whose correction ranges from -14.3 to +16.4 minutes throughout the year. This variation is nearly sinusoidal and can be approximated by a formula.

Mean Solar Time (MST) simplifies TST by assuming a uniform Earth rotation. Universal Time (UT), also known as Greenwich Mean Time (GMT), is the MST at the Greenwich meridian. Legal Time (LT) is the official time used in each country. It is based on the time zone and local longitude.

For a given location like Antananarivo (L = 47°53′ E, time zone N′ = +3), a relation links TST, UT, and LT. This study helps to understand the local solar time structure, which is crucial for energy applications and climate modeling.

$$TST = LT + \frac{L}{15} - N' + \frac{ET}{60} \quad (1)$$

where TST is the True Solar Time, LT is the Legal Time, ET is the Equation of Time correction, L is the longitude of the location (e.g., 47°53′ E for Antananarivo), and N′ is the time zone number (e.g., +3 for Antananarivo).

3. Earth's Atmosphere and Solar Radiation Budget

The Earth's atmosphere is structured in superimposed layers: troposphere, stratosphere, mesosphere, and thermosphere. Each layer has specific thermal and chemical properties. The troposphere hosts most weather phenomena. The stratosphere contains the ozone layer, which absorbs ultraviolet radiation. The mesosphere and thermosphere complete the atmospheric structure, with temperature varying with altitude.

Dry air consists mainly of nitrogen (78%), oxygen (21%), and trace gases. Water vapor, carbon dioxide, and aerosols both natural and anthropogenic significantly affect solar radiation absorption. These components filter radiation across selective spectral bands.

The solar radiation received at the Earth's surface includes three components: direct radiation (unscattered), diffuse radiation (scattered by the atmosphere), and reflected radiation (albedo), which depends on surface characteristics. The sum of these components is defined as global radiation.

Irradiation measures the energy received over a period, commonly expressed in Wh/m². The clearness index, defined as the ratio of global to extraterrestrial radiation, classifies sky conditions (clear, partly cloudy, overcast). This index is essential for solar energy assessments and climatic analysis, [6].

$$G = G_d + G_r + G_{dif} \quad (2)$$

Where G_d denotes the direct solar radiation, G_r the reflected radiation, and G_{dif} the diffuse radiation.

4. Energy Flux and Angular Distribution of Radiation

Energy flux represents the amount of energy carried by a light beam per unit of time. It is expressed in watts and depends on the orientation and distance between the source and the receiving surface. A point source emits radiation toward a surface within a solid angle $d\Omega$, [7].

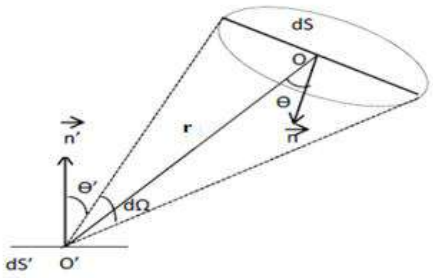

Fig.1 : Illustration of the energy flow

Where $\vec{n}$ and $\vec{n'}$ are the normal vectors to the surface elements dS and dS', respectively;

$r = O'O$ is the distance between the radiation source and the point on dS',θ is the angle between $\vec{n}$ and the emitted radiation; θ' is the angle between $\vec{n'}$ and the incoming radiation; and $d\Omega$ is the solid angle under which dS', is viewed from point O'.

The energy flux density is proportional to the source's luminance in the given direction. By integrating the luminance over the entire solid angle, the total energy flux received by the surface is obtained.

$$d\phi = \iint_s L' \frac{dS\, dS' \cos\theta\, \cos\theta'}{r^2} \quad (3)$$

Table 1 : Comparison of Solar Technologies and Role of Local Solar Time

Conversion Principle	Use of thermal collectors and heat transfer fluids	Use of semiconductor cells (P-N junction) to convert photons
Type of Process	Thermodynamic process	Chemical/electronic process
Main Compo-nents	Glazed collectors, metallic absorbers, heat pipes, fluid (water, glycol, air)	Photovoltaic cells (silicon), anti-reflective coating, electrodes
Output Type	Thermal energy for domestic hot water, space heating, drying, or cooling	Direct current (DC) electricity
Energy Storage	Stored as heat in fluids or thermal masses	Stored in batteries
Applicat-ions	Home heating, water heating, greenhouses, swimming pools, solar cooling	Power supply for electronic devices, lighting, buildings, solar farms
Efficiency Influences	Strongly influenced by sunlight availability, insulation, night conditions	Influenced by light intensity, cell temperature, and aging
System Type	Passive or active systems (with fluid circulation)	Standalone systems or grid-connected with battery storage
Advanta-ges	High efficiency for thermal energy production	Direct electricity generation, scalable
Disadva n-tages	Difficult energy storage and regulation,	Lower conversion efficiency, thermal losses at high

	performance drop in low sunlight conditions	temperatures

- ***Solar thermal collector***

The solar thermal collector converts solar radiation into heat using a heat transfer fluid. The addition of baffles improves thermal transfer in the air channel of the collector. The metallic absorber captures solar energy and transfers it to the fluid by conduction. The glazing limits thermal losses via greenhouse effect and optimizes solar absorption. The thermal insulation reduces heat loss on the lower and lateral sides of the collector. The copper coil increases thermal conductivity and air heat retention capacity.

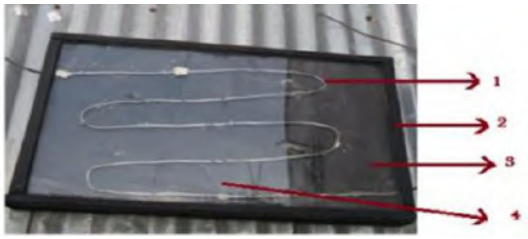

Fig.2 : Components of a flat-plate glazed collector.

The system (figure 2) consists of four main components: **1.**a metal coil for heat exchange, **2.** a black wooden frame providing structural support, **3.** a black sheet metal absorber surface to maximize solar energy capture, and **4.** a transparent cover that reduces heat loss while allowing solar radiation to pass through, [8].

- ***Heat transfer fluid***

The heat transfer fluid carries thermal energy in liquid or gaseous form. Air is used as the heat carrier despite its low thermal conductivity. A metal coil extends the air path and enhances thermal contact with the absorber. The heated air is reinjected into the box to optimize heat exchange. A built-in fan supports forced convection without overheating risk. Cold water is used as a second fluid to provide system cooling.

- ***Thermal Resistance***

The thermal resistance takes over when the outside temperature falls below the comfort reference. It provides fast and accurate heating through an automatically controlled regulation system. Powered by the battery, it complements the solar collector during periods of low sunlight. It regulates the return circuit temperature to prevent overheating in the air chamber. Its efficiency depends on the type of heat transfer: conduction, convection, or radiation. Its integration into the airflow circuits of the energy box enhances thermal stability and system performance.

$$R_C = \frac{\text{Difference between the interior temperatures of the casing and the room}}{\text{Heat flux}} \quad (3)$$

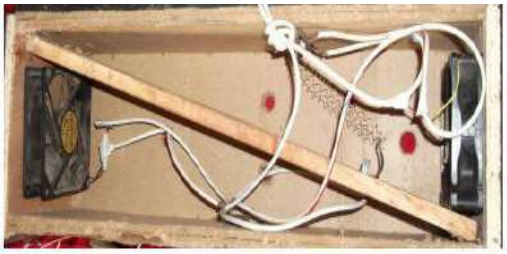

Fig.3: Photo of the air circuits inside the energy casing [24].

5. Ventilation

Ventilation ensures thermal comfort and air quality in a bioclimatic house. It affects temperature, air velocity, and humidity to improve indoor well-being. Natural ventilation uses air density differences to passively supply fresh air. Mechanical ventilation uses fans to actively control airflow and include heating or cooling. The fan coil unit enables heat exchange between air and the heat-transfer fluid inside the air chamber. Warm air is blown into the room at suitable pressure and speed depending on the season to maintain comfort.

6. Modeling and analysis of the systems used

The thermal modeling is based on simplifying assumptions to ease system analysis. A quasi-steady-state regime is assumed, with materials having constant properties. Temperatures within the collector and room are treated as uniform, and secondary thermal losses are neglected. The experiment was conducted over 30 days between July and August in Antananarivo. Ambient air temperature, affected by various climatic factors, plays a key role in thermal comfort. It is modeled using an approximate equation based on solar time and local weather data.

$$T_e(J,t) = \frac{T_{Max}(J)+T_{Min}(J)}{2} + [\frac{T_{Max}(J)-T_{Min}(J)}{2}]\sin(15t-120) \quad (4)$$

Where t is the true solar time (with $t = 12$ at noon, t = 0 or 24 at midnight, $t = 13\ at\ 1\ PM$, $t = 19\ at\ 7\ PM, t = 23\ at\ 11\ PM$, $t = 11\ at\ 11\ AM$, etc.), and the monthly daily averages of minimum temperature $T_{Min}(J)$ and maximum temperature $T_{Max}(J)$ over 24 hours were recorded during local measurements in Antananarivo from July to August 2022, [9].

7. Thermal balance of the system

The thermal balance of the solar collector is established from the solar flux absorbed by the absorber, the useful heat flux transferred to the heat transfer fluid, the heat losses through insulation governed by Newton's law, and the stored energy within the collector depending on the air mass, its specific heat capacity, and the absorber's temperature variation, while the global, internal, and optical efficiencies of the collector vary based on internal parameters such as orientation and external factors such as solar irradiance, and the thermal inertia is experimentally determined by the temperature difference between the fluid's inlet and outlet, whereas the absorber's thermal diffusivity related to its thermal conductivity, density, and specific heat promotes heat transfer by conduction toward the heat transfer fluid within the collector, in interaction with the glass cover and air chamber.

III. ANALYTICAL METHOD

The analytical method helps properly size the solar installation to meet winter thermal needs. The system uses air-based collectors operating at low temperature with high airflow. A heat-transfer fluid, typically air, carries the collected heat to the living space. The system includes a heat exchanger or storage unit to ensure continuous energy supply. The study calculates the hot air and heating needs to maintain indoor comfort. Electric heaters and fans are added to overcome solar system limitations, especially at night.

1. Energy signature method

The method is applied under steady-state conditions where the building reaches thermal equilibrium with its surroundings. It models the heating load based on external factors such as solar radiation and outdoor temperature. The simplified thermal balance is expressed as a linear relation between heat load and climate conditions. Only heating or cooling periods are considered in the calculation. Assuming stable indoor temperature allows further simplification of the equation. The coefficients are estimated through linear regression using collected daily, weekly, or monthly data, [10].

$$Q' = x_r + y_r T_{ext} \quad (5)$$

The coefficients x_r and y_r_are estimated using linear regression based on scatter plots of daily, weekly, or monthly data collected at the household level, where Q' represents the heating load and T_{ext} the average outdoor temperature (°C).

2. Model to study the variation of outdoor temperature and solar irradiance

The model considers variations in solar radiation and outdoor temperature to evaluate the heating load. The linear regression equation links heating flux to solar input using least squares-calculated coefficients. Energy signature methods analyze the building's thermal behavior based on daily, weekly, or monthly data. They exclude transient states to better detect unusual energy consumption. Thermal models use outdoor temperature and solar energy both direct and diffuse as key parameters. Heat exchange occurs by convection at surface contact and by radiation depending on absorbed solar energy, [11].

$$(\rho C)_i V_i \frac{dT_i}{dt} = \sum_k \Phi_{ik}(t) + P_i(t) \quad (6)$$

where $(\rho C)_i$ is the heat capacity of the material composing the volume V_i is an elementary volume of the building, $P_i(t)$ represents the set of external energy inputs; and $\Phi_{ik}(t)$ denotes the heat fluxes exchanged at the interfaces of V_i .

3. Method for calculating the power of the collector

The thermal power of the collector is calculated based on air flow rate, air heat capacity,

and the temperature difference between inlet and outlet. The volumetric heat capacity of air is estimated at 1.2 J/K/L under standard conditions. An initial method using volumetric flow showed limitations due to multiple unverified assumptions. An alternative and more accurate approach uses the mass flow rate and an average specific heat capacity of 1017.5 J/kg°C. This method allows for temperature-independent calculations if the collector is airtight. Energy consumption for heating, cooling, and air conditioning must comply with the thermal energy standards and remain within prescribed limits, [12].

$$P = 1.683E_{ng} - 17.11\Delta\theta \quad (7)$$

where E_{ng} represents the solar irradiance in W/m², and $\Delta\theta$ denotes the difference between the average inlet-outlet temperature of the system and the ambient temperature.

4. *Method for calculating the overall power of the system*

The global power of the system is defined according to the NFP50-501 standard from September 1977. It depends on the received solar irradiance and the thermal difference between the system and outdoor air. The average system temperature is calculated from the inlet and outlet temperatures. This average temperature is then compared to ambient temperature to assess performance. The full expression for global power includes surface area and solar radiation intensity. This method allows for evaluating the overall energy efficiency of the solar installation, [13].

$$P = Q_m C_p (T_{cs} - T_{fe}) \quad (8)$$

Where Q_m is the mass flow rate in liters or kg/s (with $Q_m = 0.02\ \text{kg/s}$ used in this study), and C_p is the specific heat capacity of air at constant pressure (in J/kg·°C).

5. *System operation: heating and cooling*

The system operates by capturing solar energy using a flat air solar collector and a photovoltaic panel. The heat transfer fluid circulates through a coil to deliver the collected heat. A valve-based control system directs the fluid flow toward the energy chamber. In winter, if the air temperature is too low, an electric resistor powered by the photovoltaic panel provides heating. In summer, when the temperature exceeds the comfort level, the fluid is routed to a cooling system using chilled water and ventilation. This operation ensures thermal regulation of the dwelling, following a thermodynamic process similar to the Carnot cycle, [15].

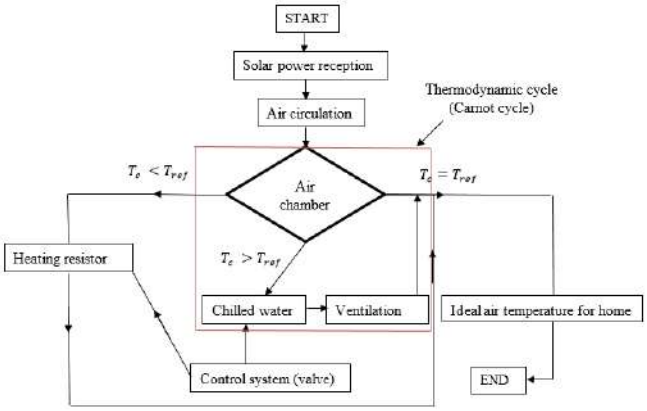

Fig.4 : Block diagram of the system operation

IV. RESULT AND DISCUSSION

1. *Results on the overall efficiency of the collector*

The coupling of thermal modeling with dynamic simulation integrates key parameters such as air temperature, heating, cooling, or ventilation intensity, enabling efficient analysis of the system's behavior under the specific climatic conditions of Analamanga; the results from the global thermal balance calculation, using a formula implemented in Matlab, show that the flat air solar collector exhibits variable thermal efficiencies throughout the day, with optimal performance when the temperature difference between the collector and the ambient air is minimal, while the collector's inclination and the incidence angle of solar radiation directly influence transmission through the glazing, thus explaining the curve overlap caused by thermal flux variations during sunlight exposure.

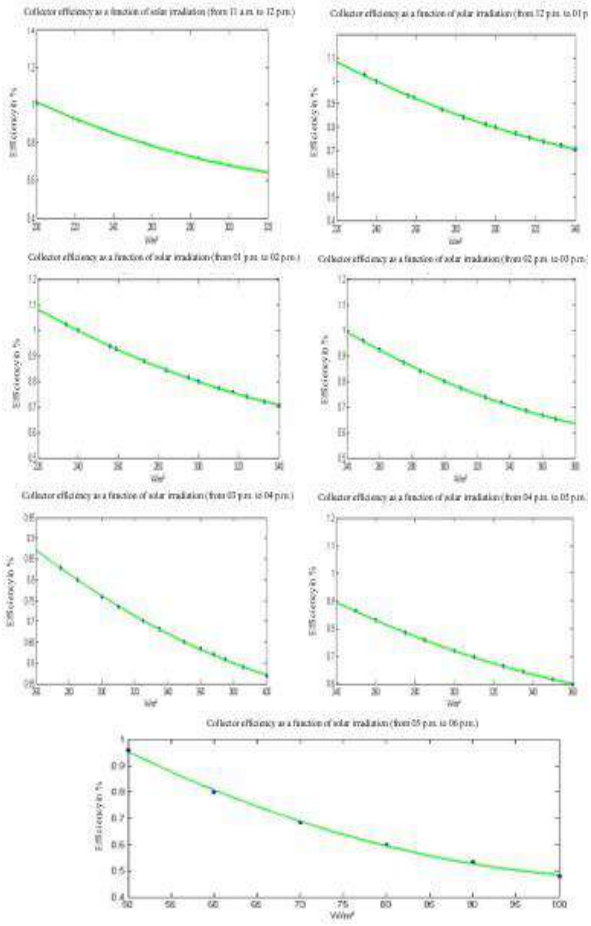

Fig.5 : Overall efficiency received by the collector

2. *Total and instantaneous power received by the collector*

The fig.6 presented illustrate the variation of global and instantaneous power received by the flat plate air solar collector throughout the day. The collected thermal power reflects the contribution of solar energy to heating demands. The calculations show that the power varies depending on sunlight exposure and time of day. The curves allow evaluation of the solar coverage in relation to total energy consumption. An energy control box, combined with a switch and a battery, ensures daily thermal management. The system can simultaneously provide heating and cooling depending on requirements. Continuous observation of the system ensures a better understanding of its operation. The capture methods, measurement series, and calculation tools enable a rigorous evaluation. This setup can also serve as a reference for comparative studies with other similar systems.

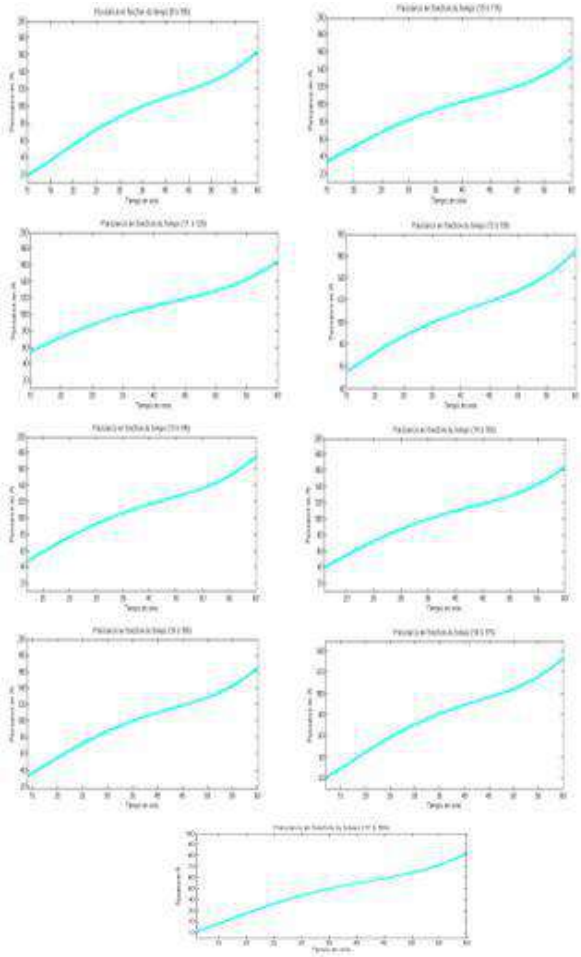

Fig.6 : Total power received by the collector

3. *Temperatures obtained in the floor*

The temperature on the floor is obtained from the calculation of the overall thermal balance of the air-heated floor used in this system. The application of this formula through the energy signature method and the Matlab software shows the temperature trend over one hour. This temperature variation is illustrated in the figure below.

The floor temperature (fig.7) gradually increases over time, starting with a slow rise during the first 40 minutes. This period indicates a significant thermal inertia of the system. After the 40th minute, the temperature rises more rapidly, reflecting a stronger activation of the heating mechanism. This shows the system's increasing thermal efficiency as time progresses.

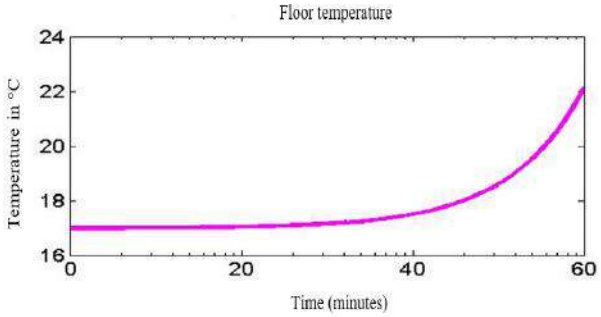

Fig.7 : Temperature obtained on the floor within one hour.

Due to the continuous increase in temperature received over one hour during the day, the indoor temperature becomes very high, exceeding the comfort temperature. However, the application of the cooling method in this system (which involves passing the heat transfer fluid through chilled water and using ventilation) stabilizes and maintains the comfort temperature in the room. Therefore, the temperature received on the floor throughout the day is shown in the curve below.

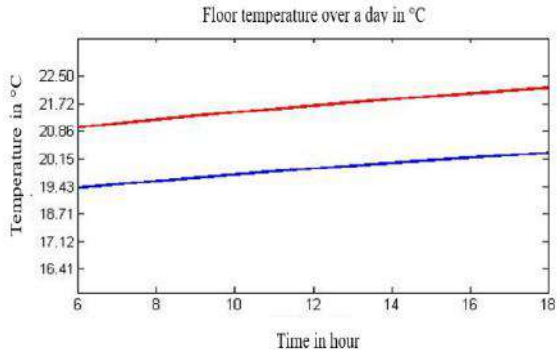

Fig.8 : Floor temperature recorded throughout the day

The floor temperature (fig.8) increases slightly from 6 a.m. to 6 p.m., reflecting a moderate variation under external conditions. The two curves likely compare two thermal scenarios or different floor layers. The red curve remains consistently higher than the blue one, suggesting better thermal performance or an additional energy input. The relatively stable slopes indicate a maintained thermal balance over time.

4. Performance coefficients

The studied system consumes little electricity and operates with various installation levels. It achieves a coefficient of performance greater than 1, proving its efficiency. The COP represents the ratio between recovered energy and energy delivered indoors. A COP of 3 means that for each 1 kWh consumed, 3 kWh of heating are produced. The COP decreases when the outside temperature is lower. Our system reached a COP of 3.38 with 160 Wh recovered and 47.2 Wh delivered, confirming its high performance.

V. CONCLUSION

The solar system studied uses air as the heat transfer fluid to heat or cool indoor spaces. It captures solar energy through an air collector and a photovoltaic panel. It provides constant thermal comfort throughout the seasons. Thus, it heats during winter and cools during summer. Then, it uses thermal storage and ventilation to regulate indoor temperature. The system shows good energy efficiency in the tropical climate of Antananarivo. It reduces fossil energy dependence and lowers household costs. Finally, it offers a sustainable, simple, and suitable solution for low-income areas.

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The Influence of Hotel Greenwashing on Visit Intentions: The Mediating Role of Green Skepticism

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Abstract *— In recent decades, with the increasingly serious environmental problems, more and more companies and consumers pay attention to practice green consumption. Based on the cognition-affect-behavior (C-A-B) theory, this study is intended to examine if cognition in the form of greenwashing, affect in the form of perceived green skepticism and behavior in the form of visiting the hotel. Through a survey-based approach and analysis, it has been found that greenwashing and green skepticism are important factors in predicting consumer visit intention. The positive influence of greenwashing cognition flows through green skepticism. Additionally, green skepticism mediates the relationship between greenwashing and green visit intention. The findings of this research contribute to the study of greenwashing in hospitality industry in the concept of sustainability.*

Keywords *— greenwashing, green skepticism, visit intentions.*

I. INTRODUCTION

In recent decades, with the increasingly serious environmental problems, more and more companies and consumers pay attention to practice green consumption. Consumers are interest in purchasing green products and services that are environmentally friendly due to environmental considerations [1, 2]. As a result, green marketing has become an essential strategy for appealing to environmentally conscious customers, many businesses are attempting to show consumers their good corporate image and social responsibility [3]. However, some corporates have adjusted their green business strategies to pretend to be green by greenwashing that is only about talking and not doing [4-6]. Aji & Sutikno indicated that the deceptive use of marketing to promote the perception of environmental-friendly image is called to as greenwashing [7]. This practice has given some consumers the negative intent to purchase these products or services, and has also increased consumer confusion when it comes to purchasing products with environmental features [7, 8].

Hotels across the globe are increasingly embracing green practices. Signs accompanying a cue for environmental concern that remind guests to turn off the lights, reuse towels or linen and use water more conservatively have become commonplace in hotels [9]. Statistics reveal eighty-five percent of U.S. hotels have some form of green practice, at the same time, seventy-nine percent of consumers found eco-friendly practices to be important. However, only fifty-six percent of hotel consumers are very skeptical about whether hotels are truly ecofriendly [10]. Obviously, Consumers' have become aware of hotels' greenwashing propensities. According to [9], hotels take to dishonest tactics to attract customers by falsely portraying themselves as environmentally friendly [11]. This perception results from the difference between hotel eco-friendly declarations and their real environmental effect by reducing green initiatives [12].

This gap can partly be explained by skepticism [13].

There is growing consumer skepticism towards companies that take opportunistic advantage of the green movement. As a result, the customers may become skeptical whether to keep on purchasing or change their behavior [14]. At times, these tactics may cause customers to have negative impact on customers' green purchase intentions [15]. Mohr, Eroğlu, & Ellen had suggested that consumers' environmental knowledge and concern can be significant triggers in generating skepticism about green marketing [16]. In fact, although many marketing and psychology researchers [17, 18] have uncovered influential factors on consumer skepticism such as their level of environmental knowledge, cynicism, and self-esteem, the hospitality literature has been tardy in examining the significance of those factors on customer attitudes and behavioral intentions [9].

In the previous literature, there have been many studies concerning causes, taxonomy and consequences of greenwashing behaviors in hospitality industry. However, the most of past research has been conducted in Western countries, specifically in the United States [9, 11, 19]. There are only few studies on greenwash behavior in the hospitality industry, particularly in developing countries. Recently several researches have targeted on developing countries such as Aintrama that explored purposely greenwashing tactics influenced customers' green purchases decision in Thailand's hospitality industry [12]. Comparing to developing countries, it exists a research gap regarding the consequence of greenwashing in developing countries, especially in hospitality industry. As a result, our study efforts to fill this gap partly fill this gap.

Furthermore, most research regards environmental concern as a direct or indirect antecedent of consumers' green purchasing intentions [1, 20] , but seldom does any study explore its moderating role between corporate misconduct and consumers' purchasing intentions [3]. According [21], consumers with a high degree of environmental concern are more likely to have a strong sense of environmental responsibility and practice environmentally-friendly behaviors, such as energy-saving, recycling, and buying environmentally-friendly products [3]. As a result, this study also explores the moderating role of environmental concern on consumers' greenwashing perceptions and green visit intentions.

II. LITERATURE REVIEW AND HYPOTHESES

2.1 Cognition-affect-behavior theory and consumer green behaviors

Several researchers employed the C-A-B scheme to develop systematic models of consumers' decision making [22, 23]. The C-A-B paradigm suggests that cognition (C) determines affect (A) which influences behavior (B). For instance, beliefs about health and ecological welfare benefits have been shown to enhance affects in the form of hedonic attitudes and then improve attitudinal loyalty and behavioral loyalty to organic food [24].

Based on the cognition-affect-behavior (C-A-B) theory, this study addresses consumers' reactions to the phenomenon of "greenwashing" in the hospitality industry. We proposed and tested a theoretical model that examined whether recognizing the perceived greenwashing caused consumer skepticism about hotel environmental claims, which in turn influenced consumer intention to visit the hotel. Additionally, the moderating effects of ecological concern on the relationship between skepticism and intention to participate and between skepticism and intention, and perceived consumer efficiency and intention to visit were examined. Rahman et al. applied C-A-B paradigm to explore consumers' reactions to the phenomenon of greenwashing in the lodging industry [9]. Similarly, Nguyen et al. employed the same paradigm to examine a model linking greenwash and green skepticism with green purchase intention [4]. This study will explore consumers' cognitive knowledge is being influenced with the greenwashing actions in the hospitality industry, which brings about their skepticism of the green hotel's claims. As a result, it affects the green visit intentions. The present study model, on the base of C-A-B paradigm, explores the mediating role of green skepticism, and the moderating role of environmental concern in the relationship between greenwashing and the visit hotel intentions.

2.2 Greenwashing and Green Skepticism

Skepticism refers to an individual's overall tendency to distrust or doubt the claims of others [18]. In

business management, this concept has been extensively examined across various contexts, including advertising, organic products, corporate social responsibility, environmental claims, and cause-related marketing [25, 26]. Consumers with high levels of skepticism tend to respond less favorably to advertisements [27]. Previous studies have found a positive association between greenwashing and green consumer skepticism [4, 7]. As Pomering and Johnson [28] indicated, skeptical individuals are more likely to critically evaluate advertising claims rather than accepting them at face value [7]. Thus, the following is hypothesized:

Hypothesis H1: Greenwashing is positively related to green skepticism.

2.3 Greenwashing and Green Visit Intention

If companies use greenwashing to deceive consumers, it can damage trust and hinder the establishment of long-term relationships, ultimately reducing purchase intentions [29, 30].Polonsky et al. showed that greenwashing introduces false environmental claims into the market, which lessens the credibility and popularity of genuinely green products [31]. Similarly, research has demonstrated that greenwashing negatively impacts word-of-mouth, green perceived quality, and green satisfaction, thereby eroding consumer trust [11, 32]. Furthermore, Nyilasy et al. [33] emphasized that greenwashing is not only an ethical failure but also severely damages consumer perception and trust.Thus, this study proposes the following hypothesis:

Hypothesis H2: Greenwashing is negatively related to green visit intentions.

2.4 Green Skepticism and Green Visit Intention

Han, Hsu, and Sheu [34] examined customers' visit intention, revisit intention, and word-of-mouth intention as primary behavioral intentions in the hotel context. Previous studies have suggested that skepticism can negatively impact brand beliefs, brand attitudes, reliance on ads, and behavioral intentions [18], [35]. Goh and Balaji [2] revealed that green skepticism negatively influenced consumers' purchase intentions for green products in Malaysia. Similarly, Nguyen et al. [4] demonstrated that green skepticism has a negative effect on Vietnamese consumers who purchase green vegetables. Furthermore, Yoon and Chen [19] found that skepticism negatively influences customers' visit intentions in the hotel industry.Thus, the following is hypothesized:

Hypothesis H3: Green Skepticism is negatively related to Green Visit Intention.

2.5 The mediating effect of Green Skepticism

Base on foregoing exploration of cognition – affect – behavior (C-A-B) paradigm, the premise of the C-A-B paradigm is that cognition (C) determines affect (A) which, in turn, results in behavior(B) [9]. Nguyen et al. [4] indicated green skepticism mediated the relationship between greenwash and green purchase intentions. Thus, the following is hypothesized:

Hypothesis H4: Green skepticism mediates the relationship between greenwash and green visit intention

III. RESEARCH METHODOLOGY

3.1 conceptual framework

The full conceptual framework is presented in the following Figure 1.

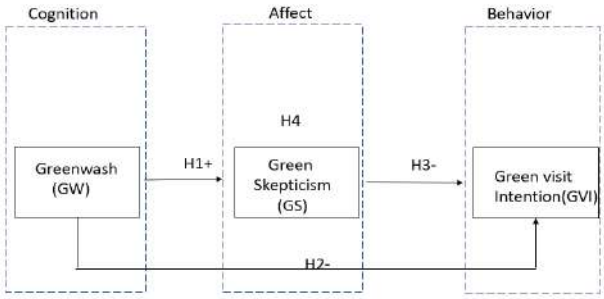

Fig. 1: The full conceptual framework

3.2 Stimulus, Data and Sampling

The target population of this study were Taiwan consumers who plan the visit hotel in the future six months. A self-report online survey was prepared using Google Form platform ensuring a diverse representation of the target population. In order to select a hotel's actual green initiatives for presenting as the survey stimulus in this study, the actual green marketing initiative of hotel reservation website in Taichung will be collected. The reason we survey the website of Taichung hospitality industry is Taichung government is promoting "Green Hotel" certification Plan. The evaluation of the certification included not offering bottle water. As a result, real-life scenario –

not offering bottle water was used. First, participants were introduced to the concept of green hotel. Participants were instructed to imagine themselves in a scenario. The scenario was a description on a hotel website that claims to be environmental-friendly by not offering bottle water. After reading the scenario, the subjects were asked to respond to questions about greenwashing, green skepticism and visit intention, Participants were also asked to fill out demographical information that included age, gender, sex, education, income, and previous experience with green hotels.

3.3 Research Measures

Table 1. Measures, list of Items and source

Variables	Items	Source
Greenwashing	1. This hotel misleads with words in its environmental features. 2. This hotel misleads with visual or graphics in its environmental features. 3. This hotel has a green claim that is vague or seemingly unprovable. 4. This hotel overstates or exaggerates how its green functionality actually. 5. This hotel leaves out or masks important information, making the green claim sound better than it is.	[11, 36]
Green Skepticism	1. I can depend on getting the truth in this environmental claim. 2. I believe this environmental claim is informative. 3. This environmental claim is generally truthful. 4. This environmental claim is a reliable source of information about the green value of the hotel. 5. This environmental claim is truth well told. 6. This environmental claim presents a true picture of the hotel. 7. I feel I've been accurately informed after reading this environmental claim. 8. This environmental claim provides customers with essential information.	[2, 19]
Green visit intention	I intend to be a customer of this hotel in the future. I am willing to stay at this hotel using the claim when traveling. I will make an effort to stay at this hotel using the claim when traveling	[9, 34]

The questionnaire was designed to assess consumers' response regarding hotel's greenwash behavior under the mediating role of green skepticism. Additionally, the study explores the moderating effect of environment concern. A questionnaire was used to collect responses in this study. Before conducting the main survey, two experts (one marketing professor, the other hotel manager) will be invited to assess the measurement items and survey instrument. The questionnaire begins with a short description of the definition of green hotels, the hotel's green initiatives, and suggested that now many hotels seem to present themselves as green hotels despite not being really green. All variables were measured by a five-point Likert scale (anchored at 1 indicates "strongly disagree", 2 "disagree", 3 "neutral", 4 "agree", and 5 "strongly agree"). First, a five-item measurement scale for greenwash was adopted from Chen et al. [11] and Laufer [36]. Then, an eight-item green skepticism scale was adapted from Goh and Balaji [2] and Yoon and Chen [19]. Finally, a three-item scale for green visit intention was adopted from Han et al. [34] and Rahman et al. [9]. All measures and items are showed in Table 1.

IV. RESULTS

To test the relationships in the proposed model, we conducted a survey using the purposive sampling

technique. The online questionnaires were collected from students at universities in Taichung, Taiwan. Some lecturer-partners who have classes at several of these universities were asked to help answer the online questionnaires. In total, there were 201 questionnaires with qualified and usable data.

Psychometrics properties of the scales Cronbach's is considered an adequate index of the inter-item consistency of independent and dependent variables. The Cronbach's value for the dimensions of this study's scales was greater than 0.7, indicating a high reliability [37] . The Cronbach's value came to 0.894, 0.724, 0.903, for greenwashing, green skepticism and green visit intention respectively.

This study applied a hierarchical regression analysis to validate Hypotheses 1 to 4. We followed the four steps of hierarchical regression analysis to conduct mediating effect validations [38]. Hierarchical regression analysis includes three models. First, the independent variables must produce an effect on the intervening variables. As shown in Table 2, Model M1 simulates the green skepticism regression analysis results. The results of adding the independent variable of greenwashing into Model M1 show that the independent variable produced a significant positive effect on the intervening variable of green skepticism (β =0.451; t= 7.124***), fulfilling the first condition of the mediating effect analysis step and supporting Hypothesis 1. Second, the independent variables must affect the dependent variables. Model M2 illustrates the green visit intention regression analysis results. The results of adding the greenwashing independent variable into M2 show that greenwashing has a significant negative effect (β =-0.154, t=-2.993**) on the dependent variable of green visit intention, supporting Hypothesis 2. Finally, we added the intervening variable of green skepticism into M3, where the intervening variable must affect the dependent variable, and the independent variable's effect on the dependent variable decreases. As Model M3 shows, the intervening variable of green skepticism had a significant negative affect (β =0.632; t= 9.939***) on the dependent variable of green visit intention. Therefore, Hypothesis 3 was supported. When validating the mediating effects, greenwashing had no effect on green visit intention (β =-0.077, t=-1.217) after green skepticism was added as an intervening variable. Consequently, the condition of Step 3 was obtained, Hypothesis 4. Was fully supported.

V. CONCLUSION AND DISCUSSION

Table 2. Hierarchical Regression Results

	M1: dependent variable= GS			M2: dependent variable = GVI			M3: dependent variable =GVI		
	B	Standardized β	t	B	Standardized β	t	未標準化係數 B	Standardized β	t
constant	4.088		29.347***	3.718		22.969***	0.977		3.195**
GW	0.316	0.451	7.124***	-0.154	-0.208	-2.993**	-0.058	-0.077	-1.217
GS							-0.670	-0.632	-9.939**
GW-greenwashing									
GS- green skepticism									
GVI- green visit intention									
M1: adjusted R^2 = 0.199 (F= 50.750***)									
M2: adjusted R^2 = 0.038 (F= 8.959**)									
M3: adjusted R^2 = 0.355 (F= 56.074***)									
*** significant at p<0.001									

This study examined how greenwashing influence visit intention and, additionally, investigated the mediating role of green skepticism. It also used the Cognition-Affect-Behavior theory to conduct the research. It was used as a way to examine how consumers' cognitive knowledge is affected by greenwashing actions in the current field. The findings of this research contribute to the study of greenwashing in hospitality industry in the concept of developing country.

As a result, all four hypotheses have been supported. First, greenwashing has shown a positive relation to green skepticism of the customers. Which means customers tend to be more critical to environmental claims and companies positioning them as environmentally friendly. Secondly, this study has revealed negative influence of greenwashing on green visit intention. It was shown in the analysis that green visit intention regresses with the influence of greenwashing. Thirdly, the study examined the relationship between green skepticism and green visit intention. Hypothesis 3, which stated that green skepticism is negatively related to green visit intention, was also supported. Customers' skepticism towards the brand leads to the lack of green visit intention. Lastly, the mediating effect of green skepticism between greenwash and green visit intention was also supported.

This study contributed to the understanding of customers perception on greenwashing propensities. However, it faced several limitations. As for data collection, the responses of students in universities of Taichung have been used as a sample, future researches can use broader the group of people to expand this study. More well-off customers can be interviewed for data collection and analysis. Additional studies can also consider researching other developing countries as the results might differ from Taiwan. Furthermore, this research specifically considered greenwashing behaviors in hospitality industry, which puts limitations on the research. Future studies should explore other fields that also have greenwashing propensities.

In conclusion, this study has emphasised the influence of hotel greenwashing on customers visit intentions and explored the mediating role of green skepticism. Companies can use the results of the research in building their image and applying green marketing strategies.

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Understanding the Role of Legal Awareness in Building E-Commerce Trust Among Gen Z Consumers

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Abstract— *This study investigates the role of legal awareness in building trust in e-commerce platforms among Generation Z consumers in Nueva Ecija, Philippines. Specifically, it examines the influence of Digital Platform Accountability (DPA), Awareness of E-Commerce Laws (AEL), and Perceived Legitimacy of Platforms (PLP) on Trust in E-Commerce Practices (TEP). A descriptive-correlational research design was employed, and data were gathered from 159 Gen Z respondents aged 18 to 26 through a validated Likert-scale questionnaire. Descriptive statistics showed that respondents generally agreed with items measuring legal awareness and trust, indicating a moderate to high level of legal consciousness. Gender-based analysis revealed a statistically significant difference in AEL, with female respondents demonstrating higher awareness. However, no significant differences were found based on online shopping frequency. Pearson correlation results indicated strong, positive, and statistically significant relationships among all constructs. Regression analysis revealed that DPA ($\beta = 0.306$, $p < .001$), AEL ($\beta = 0.246$, $p = .002$), and PLP ($\beta = 0.265$, $p = .002$) are all significant predictors of TEP, with the model explaining 62.3% of the variance ($R^2 = 0.623$). These findings underscore the importance of strengthening legal literacy, enhancing platform accountability, and promoting perceived legitimacy to foster trust in e-commerce among digital-native consumers. The study recommends integrating legal awareness into digital education programs, developing gender-sensitive campaigns, and fostering public-private collaborations to improve access to legal information. It also highlights the need for future research on other demographic groups and emerging e-commerce technologies. Overall, the research contributes valuable insights into the legal and behavioral dimensions of Gen Z's online shopping behavior.*

Keywords— ***legal awareness, e-commerce trust, Generation Z, digital platform accountability, e-commerce laws, perceived legitimacy, consumer behaviour***

I. INTRODUCTION

With the increasing integration of e-commerce into the daily lives of Filipino consumers, particularly among the tech-savvy Generation Z, the issue of trust in online platforms has become a critical concern. As the first generation to grow up fully immersed in the digital age, Gen Z's online shopping habits are significantly shaped by their unique traits and preferences (D. & Waghmare, 2024). E-commerce platforms and marketing content are used differently by different generations, making it crucial for businesses to adapt to Gen Z's evolving expectations (Syamsudin et al., 2025). Understanding the factors that influence online purchase decisions—such as trust, perceived legitimacy, and legal awareness—is essential for optimizing consumer engagement and conversion rates (Sonia, 2024; D. & Waghmare, 2024).

Legal awareness in e-commerce includes understanding laws related to data protection, privacy policies, return and refund mechanisms, and seller accountability. For Generation Z—those born from the mid-1990s to early 2010s—who rapidly

embrace new technologies and trends (D. & Waghmare, 2024), this awareness is essential not only for their protection but also for fostering a trustworthy online marketplace. However, studies in the Philippine context, especially in provinces like Nueva Ecija, remain limited.

This study seeks to investigate the relationship between the level of legal awareness and the level of trust in e-commerce platforms among Gen Z consumers in Nueva Ecija. Specifically, it examines whether knowledge of digital platform accountability (DPA), awareness of e-commerce laws (AEL), perceived legitimacy of platforms (PLP), and trust in e-commerce practices (TEP) are significantly related. The findings aim to inform strategies that enhance safe online practices among youth and guide educational campaigns and policy improvements. The statistical relationships among these variables were supported by correlation and regression analyses conducted on responses from 159 Gen Z participants

II. REVIEW OF RELATED LITERATURE

2.1. Digital Platform Accountability Affects Trust in E-Commerce

Trust is an essential element in e-commerce, influencing customers' decisions, especially when risks are perceived (Le & Hoang, 2020). E-commerce platforms risk losing their ethical standing and full potential due to a lack of consumer confidence, highlighting the critical role of trust (Singh et al., 2024). To foster trust, e-commerce platforms should focus on technology and relational aspects (Ratnasingam, 2005). Trust in e-commerce is particularly vital because transactions carry more risk and uncertainty (Esmaeili et al., 2015). The safety of e-commerce resources, including authenticity, integrity, availability, privacy, confidentiality, and non-repudiation, requires careful consideration (Ghazali et al., 2019). Institutional structures are fundamental to building trust, with well-designed systems fostering success (Sun et al., 2025). When shopping online, consumers face risky situations, relying on e-vendors to handle their private information and transactions honestly and professionally (Bauman & Bachmann, 2017). Consumers' confidence in online transactions is crucial for the sustained expansion of e-commerce (Ahmed et al., 2007). E-commerce platforms face significant challenges due to consumers' lack of trust in merchants, technology, and the legal and financial infrastructures (Patton & Jøsang, 2003).

2.2 Awareness of E-Commerce Laws Affects Trust in E-Commerce

E-commerce platforms must prioritize consumer protection, education, and control, possibly through dedicated website sections that explain data security and privacy practices to build transparency and trustworthiness (Singh et al., 2024). Understanding these differences is crucial for improving institutions and customizing e-commerce platforms, especially since consumer and seller motivations differ, with consumers seeking quality and affordability and sellers aiming for long-term profitability (Sun et al., 2025). Trust is crucial in e-commerce because it reduces uncertainty and perceived risk (Malik & Kumar, 2021). Building trust in e-commerce involves considering the internet as a shopping channel and the e-vendor as a business partner (Kim, 2014). Trust plays a pivotal role in e-commerce, affecting user satisfaction and platform usage (Tam et al., 2019). Trust is crucial for e-commerce success, especially due to factors like online payment security, company reliability, and privacy policies (Gefen, 2000). Building trust is difficult because e-commerce relies on IT infrastructure and digital components, involving multiple parties (Alkhalil & Siddiqui, 2018). Considering the multifaceted nature of website credibility is more complex than human buyer-human seller relations (Guido et al., 2010).

2.3. Perceived of Legitimacy of Platforms Affects Trust in E-Commerce

Consumers who perceive a high risk in online transactions are likely to anticipate potential losses, diminishing their trust in the merchant (Hong & Hoon, 2013). Institutional trust and economic incentives can reduce consumer-perceived risk (Thaw et al., 2009). Assuring customers that their personal information will be secure is crucial for e-retailers to achieve greater success, as is providing secure transaction facilities (Habib & Hamadneh, 2021). Trustworthiness is essential since no one will spend money at an online store they don't trust, no matter how user-friendly it is (Lanford & Hübscher,

2004). The need to trust online providers is heightened by the anonymity and virtual nature of the global marketplace, making security concerns more prominent (Kuruwitaarachchi et al., 2019). For continued efficiency and utility of the internet, governments and industries must restore users' trust in commercial and non-commercial interactions (Chik, 2005). Trust in e-commerce is also influenced by website interface quality and perceived privacy, highlighting the need for user-friendly and secure platforms (Roy et al., 2001) (Thaw et al., 2012). This is achieved when consumers believe in a platform's reliability (Bilal et al., 2021). Trust in online shopping is built on the belief that vendors are honest, have secure websites, and offer user-friendly interfaces (Gefen et al., 2003). E-commerce success hinges on establishing and maintaining trust, which is closely related to website quality (Roy et al., 2001).

III. METHODS

This study utilized a quantitative, descriptive-correlational research design to examine the association between legal awareness and trust in e-commerce among Generation Z in Nueva Ecija. The research focused on four key constructs: Digital Platform Accountability (DPA), Awareness of E-Commerce Laws (AEL), Perceived Legitimacy of Platforms (PLP), and Trust in E-Commerce Practices (TEP), as reflected in the structured questionnaire.

A total of 159 Gen Z respondents \in Nueva Ecija were selected using purposive sampling. The participants, aged 18 to 26, were surveyed using an online questionnaire administered via Google Forms. The instrument employed a Likert scale to measure the constructs and was validated through expert review and pilot testing. Data were analyzed using descriptive statistics, Pearson correlation, and linear regression through Jamovi software.

The study adhered to ethical research practices. Participants provided informed consent prior to the survey, and anonymity and confidentiality were strictly maintained. The research protocol complied with institutional ethical guidelines and respected the voluntary participation of all respondents.

IV. RESULTS AND DISCUSSION

Table 1: Descriptive Statistics of Legal Awareness and Trust in E-Commerce Among Gen Z by Online Shopping Frequency (N = 159)

Shopping Frequency	N	DPA	AEL	PLP	TEP
Daily	13	3.18 (0.53) (A)	3.25 (0.57) (SA)	3.2 (0.48) (A)	3.17 (0.55) (A)
Once a week	43	3.01 (0.59) (A)	3.02 (0.56) (A)	2.96 (0.56) (A)	2.93 (0.56) (A)
2-3 times a week	26	3.27 (0.5) (SA)	3.18 (0.56) (A)	3.22 (0.52) (A)	3.11 (0.48) (A)
Once a month	16	2.96 (0.37) (A)	3.02 (0.43) (A)	3.0 (0.29) (A)	2.86 (0.32) (A)
2-3 times a month	45	2.96 (0.67) (A)	2.99 (0.66) (A)	2.99 (0.7) (A)	2.82 (0.62) (A)
Rarely	16	3.13 (0.3) (A)	2.91 (0.66) (A)	2.98 (0.5) (A)	3.01 (0.42) (A)

Note: 1.00–1.74 = Strongly Disagree (SD), 1.75–2.49 = Disagree (D), 2.50–3.24 = Agree (A), 3.25–4.00 = Strongly Agree (SA)

The descriptive results reveal that all Gen Z respondents, regardless of online shopping frequency, generally "Agree" on the constructs measured—Digital Platform Accountability (DPA), Awareness of E-Commerce Laws (AEL), Perceived Legitimacy of Platforms (PLP), and Trust in E-Commerce Practices (TEP)—with mean scores ranging from 2.82 to 3.27 based on a 4-point Likert

scale interpretation. Among the groups, those who shop daily reported the highest level of trust (TEP mean = 3.17), while those who shop 2–3 times a month exhibited the lowest (TEP mean = 2.82), although still within the "Agree" category. This trend suggests that more frequent engagement with e-commerce may enhance trust and awareness levels. Notably, no group scored in the "Disagree" or "Strongly Disagree" range, indicating an overall positive perception of legal aspects and trust in e-commerce among Gen Z consumers in Nueva Ecija.

Table 2: Descriptive Statistics of Legal Awareness and Trust in E-Commerce Among Gen Z by Gender (N = 159)

Gender	DPA	AEL	PLP	TEP
Female	3.11 (0.553) Agree (A)	3.13 (0.544) Agree (A)	3.08 (0.556) Agree (A)	2.99 (0.536) Agree (A)
Male	2.97 (0.57) Agree (A)	2.9 (0.642) Agree (A)	2.95 (0.582) Agree (A)	2.88 (0.548) Agree (A)

The descriptive statistics indicate that female respondents scored slightly higher than male respondents across all four constructs: Digital Platform Accountability (DPA), Awareness of E-Commerce Laws (AEL), Perceived Legitimacy of Platforms (PLP), and Trust in E-Commerce Practices (TEP). Specifically, females had the highest mean in AEL (3.13), while males reported the lowest in the same variable (2.90). Standard deviations for males were consistently higher than those for females, suggesting more variability in their responses. Despite these slight differences, both genders generally fell within the "Agree" range (2.50–3.24), based on the Likert scale interpretation. This suggests that both male and female Gen Z consumers in Nueva Ecija hold moderately positive perceptions of legal awareness and trust in e-commerce, with females showing slightly more favorable responses.

Table 3: One-Way ANOVA by Gender

Variable	F	df1	df2	p
DPA	2.15	1	110.1	0.145
AEL	5.25	1	98.3	0.024
PLP	1.75	1	108.7	0.188
TEP	1.69	1	110.8	0.197

The results show that among the four constructs, only Awareness of E-Commerce Laws (AEL) exhibited a statistically significant difference by gender, $F(1, 98.3) = 5.25$, $p = .024$. This implies that male and female Gen Z respondents differ in their awareness of legal regulations related to e-commerce, with females generally showing higher awareness based on previous descriptive results. The differences in Digital Platform Accountability (DPA), Perceived Legitimacy of Platforms (PLP), and Trust in E-Commerce Practices (TEP) were not statistically significant ($p > .05$), indicating that gender does not significantly influence these dimensions.

Table 4: One-Way ANOVA by Shopping Frequency

Variable	F	df1	df2	p
DPA	1.557	5	54.5	0.188
AEL	0.816	5	51.6	0.544
PLP	1.22	5	54	0.312
TEP	1.584	5	53.4	0.18

The ANOVA results indicate that shopping frequency does not significantly affect any of the constructs: DPA, AEL, PLP, or TEP, with all p-values greater than .05. This suggests that how often Gen Z shops online—whether daily, weekly, or rarely—does not lead to significant differences in their legal awareness or level of trust toward e-commerce. While descriptive trends suggested slightly higher means among more frequent shoppers, the differences were not statistically meaningful.

Table 5: Pearson Correlation Matrix Among Key Constructs (N = 159)

	DPA	AEL	PLP	TEP
DPA	—			
AEL	.739***	—		
PLP	.753***	.776***	—	
TEP	.724***	.718***	.724***	—

The correlation analysis reveals strong and statistically significant positive relationships among all key variables in the study ($p < .001$). Notably, Awareness of E-Commerce Laws (AEL) showed the highest correlation with Perceived Legitimacy of Platforms (PLP) ($r = .776$), suggesting that when Gen Z respondents are more informed about legal protections and policies, they are more likely to view e-commerce platforms as legitimate. Similarly, Digital Platform Accountability (DPA) also demonstrated strong positive correlations with both PLP ($r = .753$) and AEL ($r = .739$), indicating that perceptions of accountability are linked with legal awareness and perceived platform legitimacy.

Trust in E-Commerce Practices (TEP) was positively correlated with all three other variables: DPA ($r = .724$), AEL ($r = .718$), and PLP ($r = .724$). These results emphasize that higher levels of legal awareness and perceptions of legitimacy and accountability significantly contribute to increased trust in e-commerce platforms among Gen Z consumers. In summary, the constructs are highly interrelated, and strengthening one (such as legal awareness) can have a reinforcing effect on others, especially trust.

Table 6: Model Fit Summary for Predicting Trust in E-Commerce Practices (TEP)

Model	R	R^2
1	0.789	0.623

Table 6 shows the model fit statistics for the regression model predicting Trust in E-Commerce Practices (TEP). The model yielded a multiple correlation coefficient (R) of 0.789, indicating a strong positive linear relationship between the combined predictors—Digital Platform Accountability (DPA), Awareness of E-Commerce Laws (AEL), and Perceived Legitimacy of Platforms (PLP)—and TEP. The coefficient of determination ($R^2 = 0.623$) suggests that approximately 62.3% of the variance in TEP can be explained by the combined influence of DPA, AEL, and PLP. This indicates a well-fitting model, demonstrating that the selected predictors account for a substantial portion of Gen Z's trust in e-commerce platforms.

Table 7: Regression Coefficients for Predicting TEP from DPA, AEL, and PLP

Predictor	Estimate	SE	t	p
Intercept	0.459	0.1582	2.9	0.004
DPA	0.306	0.0779	3.93	<.001
AEL	0.246	0.0775	3.17	0.002
PLP	0.265	0.0823	3.22	0.002

Table 7 presents the regression coefficients for the predictors of TEP. All three variables—DPA, AEL, and PLP—were found to be statistically significant positive predictors of trust in e-commerce. Specifically, DPA had the strongest effect ($\beta = 0.306$, $p < .001$), followed by PLP ($\beta = 0.265$, $p = .002$) and AEL ($\beta = 0.246$, $p = .002$). These findings imply that Gen Z consumers are more likely to trust e-commerce platforms when they perceive those platforms as accountable, are aware of relevant e-commerce laws, and believe the platforms are legitimate. The intercept of 0.459 also indicates the baseline level of trust when all predictors are at zero, although this has less practical significance. Overall, the model suggests that improving accountability, legal literacy, and platform credibility can significantly enhance consumer trust.

V. CONCLUSION AND RECOMMENDATIONS

The study demonstrates that legal awareness plays a crucial role in shaping trust in e-commerce platforms among Generation Z consumers in Nueva Ecija. The findings revealed that Gen Z respondents generally agree that they are aware of legal protections such as data privacy, e-commerce laws, and the legitimacy of online platforms. Strong and statistically significant correlations were found among all legal awareness constructs and trust, and regression analysis confirmed that Digital Platform Accountability (DPA), Awareness of E-Commerce Laws (AEL), and Perceived Legitimacy of Platforms (PLP) significantly predict Trust in E-Commerce Practices (TEP). While shopping frequency did not yield significant differences, gender emerged as a factor, with female respondents showing higher legal awareness in AEL. These insights highlight the importance of legal education in fostering trust in digital transactions. Based on these findings, it is recommended that legal literacy be integrated into digital education programs, especially at the university level, to ensure that young consumers are equipped with essential knowledge of their rights and protections in online environments. E-commerce platforms should also enhance transparency and accountability by clearly communicating policies related to returns, data protection, and seller verification. Furthermore, gender-sensitive awareness campaigns may be necessary to address disparities in legal knowledge, particularly among male users. Lastly, public-private collaborations are encouraged to promote accessible and user-friendly legal information, while future research could explore other demographics, emerging technologies, or cross-border e-commerce issues to deepen our understanding of trust in online commerce.

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Performance Analysis of a Solar Air Heating System for Thermal Comfort in Tropical Buildings: Case Study in Madagascar

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Abstract *— This paper investigates the performance of a solar air collector integrated into a hybrid heating and cooling system for buildings in tropical climates, specifically in Madagascar. The study analyzes internal and external heat gains, calculates the thermal loads, and evaluates the efficiency of the solar system based on real temperature measurements. The results show that the solar collector can ensure thermal comfort, especially during morning and evening periods, and can also be used for domestic hot water production. With a coefficient of performance (COP) of 2 and a total installation cost significantly lower than conventional systems, the proposed solution proves to be energy-efficient, cost-effective, and suitable for local implementation. The system offers a sustainable alternative to conventional air conditioning by using locally available materials and renewable energy.*

Keywords *— **Air conditioning, Energy efficiency, Renewable energy, Solar collector, Thermal comfort***

I. INTRODUCTION

Air conditioning refers to a technique used to control the indoor climate of a closed space. Thus, temperature, humidity, and air quality are regulated to ensure thermal comfort. Since ancient times, civilizations have sought natural methods to reduce indoor heat. Egyptians and Greeks used water evaporation through porous jars to cool the air. In the 19th century, the first vapor-compression refrigeration machines marked the rise of modern cooling, [1], [2]. In 1834, Jacob Perkins built a mechanical compression machine using ether as a refrigerant, [3]. In 1842, John Gorrie developed a device for making ice, considered a precursor to air conditioning, [4]. Then, in 1859, Ferdinand Carré introduced an absorption system using water and ammonia, [5]. The 20th century brought widespread integration of air conditioning in vehicles, starting in the U.S. in 1955. Today, air conditioning is a standard technology offering discretion, energy efficiency, and health-enhancing comfort, [6].

This work aims to evaluate how air conditioning systems can provide comfort while reducing energy consumption. It analyzes internal and external heat gains to optimize cooling and heating efficiency. Then, it proposes the integration of solar collectors to improve energy performance and reduce operating costs. Finally, the goal is to demonstrate a sustainable solution adapted to tropical climates like Madagascar.

To reach this objective, the study begins by explaining the principles and functioning of air

conditioning. Then, it presents the criteria for thermal comfort and the calculation of heating and cooling loads. Next, it examines different types of air conditioning systems and their energy consumption. Finally, it proposes a hybrid solution combining conventional air conditioning with solar thermal collectors and evaluates its efficiency and cost-effectiveness.

II. AIR CONDITIONING

In residential buildings, air conditioning ensures thermal comfort by lowering indoor temperatures by 5 to 8 °C compared to outdoors during hot periods, and by providing heating during cold periods, [7]. Thus, it also dehumidifies the air to maintain optimal indoor comfort. However, air refrigeration is energy-intensive because it offsets thermal gains from solar radiation, air renewal, and internal activities. Sensible heat results from the temperature gap between inside and outside, while latent heat is linked to air dehumidification. Moreover, occupants and lighting contribute to both sensible and latent internal gains. Finally, reducing cooling energy consumption requires solar protection, airtightness, and precise control of air conditioning settings to maintain a constant indoor atmosphere.

2.1. Thermal Comfort Optimization through Air Conditioning Performance Analysis

An air conditioner operates on the same principle as a refrigerator: it removes heat from a room and releases it outside using a compressor filled with refrigerant, [8]. Thus, energy consumption depends directly on the set temperature and operating hours, especially when the room is poorly insulated. Then, the lower the desired indoor temperature, the higher the energy use, following an almost linear relationship particularly in sun-exposed spaces. To properly assess air conditioning performance, key physical parameters must be considered: temperature, heat, power, pressure, and humidity. These values, expressed in standard units (°C, W, J, Pa, %), help quantify thermal comfort objectively. Finally, air humidity plays a critical role in comfort perception and must be managed alongside temperature control.

2.2. Determinants of Thermal Comfort and Seasonal Adaptation Strategies

Thermal comfort refers to the state of physical well-being experienced by the human body in response to the thermal environment, regardless of outdoor conditions, [9]. Thus, it is influenced by factors such as metabolism, clothing, air and surface temperatures, relative humidity, and air velocity. In thermal stress situations, the body reacts through behavioral adjustments or physiological responses. Then, heat is exchanged between the body and the surroundings via conduction, convection, radiation, and evaporation. In winter, ensuring comfort involves proper insulation, suitable glazing, controlled heating, and maintaining relative humidity between 40% and 60%. Finally, in summer, comfort is achieved by reducing solar and internal heat gains, enhancing natural ventilation, and keeping indoor temperatures between 18 °C and 25 °C with air speed under 0.2 m/s.

$$T_{operative} = \frac{T_{wall}+T_{air}}{2} \quad (1)$$

2.3. Cooling and Heating Capacity Analysis for Optimal Air Conditioning Performance

The cooling power helps to cool the air in a specific space. It prevents thermal shocks to ensure comfort. This power must be calculated through a detailed heat load analysis. The thermal balance includes all internal and external heat sources. The temperature difference between indoors and outdoors should not exceed 8°C. An undersized unit cools insufficiently. An oversized unit consumes too much and causes discomfort, [10].

The heating power of an air conditioner applies to units that can produce both cold and heat, using either electric resistance or reversible operation. Thus, electric resistance heating spreads heat via ventilation, while reversible systems work like heat pumps, with a high COP and the ability to extract heat from the outside. Then, dehumidification occurs during cooling mode and is measured in liters per day, directly improving indoor comfort. The power consumption, expressed in watts, varies between average and peak values, and plays a key role in long-term energy cost. Air conditioning systems must be sized based on thermal load calculations, which include internal gains (from people, lighting, and appliances) and external gains (solar radiation, conduction, and infiltration). Finally, the total thermal load is the sum of both sensible (QS) and latent (QL)

loads, as defined in equation (2).

$$Q_T = Q_L + Q_S \quad (2)$$

2.4. Classification and Functional Diversity of Air Conditioning Systems

There are different types of air conditioners designed to meet specific thermal needs of buildings. Thus, the direct expansion air conditioner cools the air directly using a refrigeration circuit filled with refrigerant. Next, monobloc systems such as mobile units or "Windows" types are built for individual use and have limited cooling capacity. Moreover, some systems use water to cool the condenser, like exposed water consoles, but they produce noise. In addition, mono-split and multi-split units, with indoor and outdoor components, provide adjustable thermal comfort for one or several rooms. Furthermore, ducted air conditioners installed in ceilings offer a discreet centralized air diffusion solution. More advanced systems such as VRV or multi-flex can cool large buildings efficiently. Finally, all these systems can be classified as individual or centralized depending on distribution mode, airflow rate, and fluid type used.

2.5. Building Thermal Science for Energy Efficiency and Comfort

Building thermal science helps to understand heat transfer in order to better design or renovate structures. Thus, it aims to reduce energy losses while ensuring thermal comfort for occupants. Next, it considers material properties such as thermal conductivity and thermal resistance. Moreover, understanding energy flows is essential to properly size technical systems. In addition, wall performance depends on its ability to resist conduction, convection, and radiation. Furthermore, glazing plays a key role through its emissivity, solar factor, and Ug coefficient. Likewise, thermal bridges, whether integrated or at junctions, must be minimized to avoid energy loss. Finally, proper thermal management reduces annual energy consumption and improves indoor comfort.

III. METHOD FOR CALCULATING THE THERMAL LOAD OF AIR CONDITIONING IN A TROPICAL CLIMATE

The calculation of thermal load in tropical climates relies on a thorough analysis of all factors affecting heat gain. Thus, the building's orientation in relation to the sun and surrounding obstacles determines solar inputs. Then, the geometry of the room (dimensions, ceiling height) affects the air volume to be cooled. The type and thickness of construction materials directly impact thermal exchange. Moreover, the color of outer surfaces influences heat absorption or reflection. External conditions and interactions with adjacent spaces also modify cooling needs. Internal heat sources such as occupants and appliances must also be considered. Finally, this method aims to optimize air conditioning systems and avoid oversizing that leads to excessive energy consumption, [11].

To determine the peak cooling load time of an air conditioner, a two-step method must be followed. First, the rooms must be properly oriented among 31 possible options; in Madagascar, located in the Southern Hemisphere, the most effective orientation is toward the Northeast. Then, the maximum refrigeration load time must be identified, which coincides with the peak solar gain. This critical hour varies depending on the building's orientation, as shown in the tropical zone table.

Table 1 : Maximum refrigeration load hours depending on room orientation in tropical climates.

Room Orientation	Number of Exposed Walls	Exposed Walls	Maximum Cooling Hours
1	1	N	14
2		NE	14
3		E	9
4		SE	10
5		S	13
6		SW	16
7		W	17
8		NW	17
9	2	N - E	9
10		NE - SE	9
11		S - E	10
12		SE - SW	15
13		S - W	16

14		SW - NW	16
15		W - N	17
16		NW - NE	17
17	3	W - N - E	16
18		NW - NE - SE	16
19		NE - E - S	10
20		SE - S - SW	15
21		E - S - W	16
22		SE - SW - NW	16
23		S - W - N	16
24		SW - NW - NE	16
25	4	S - W - N - E	15
26		SW - NW - NE - SE	16

3.1. Internal Heat Gains

3.1.1 Gains from Occupants in the Room

They are based on the indoor temperature and the activity level of the people, [12]. These loads are divided into two types: sensible heat and latent heat.

$$Q_{sécl} = \frac{C_{sécl} * n_{écl} * \Delta t}{24} \quad (3)$$

Where $Q_{sécl}$ represents the heat gain from lighting, calculated using the number of lamps ($n_{écl}$), their total operating duration (Δt), and the sensible heat per lamp ($C_{sécl}$), which depends on the lamp type

$$Q_{locc} = \frac{C_{locc} * n_{occ} * \Delta t}{24} \quad (4)$$

Where Q_{locc} represents the latent heat gain from occupants, determined using the latent heat per person (C_{locc}) provided in Table 1.

The sensible and latent heat gains from occupants depend on the indoor ambient temperature and the level of activity.

Table 2 : Heat emitted by people under optimal indoor temperature conditions.

Activity	Heat Emission by Activity and Ambient Temperature						Total Heat Emission [W]
	Sensible Heat [W]	Latent Heat [W]	Sensible Heat [W]	Latent Heat [W]	Sensible Heat [W]	Latent Heat [W]	
	25 °C		26 °C		27 °C		
Sitting at rest	65	37	62	40	60	42	102
Light work	67	49	63	59	56	60	118
Standing, slow walking	68	63	65	67	57	74	131
Eating	77	84	71	90	64	97	161
Easy work	80	140	72	148	67	153	220
Dancing	88	161	80	169	75	174	249
Heavy work	149	277	142	284	138	290	427

3.1.2 Gains from Lighting

Lighting contributes only to sensible heat gains, as it converts the electrical energy consumed into heat.

$$Q_{sécl} = \frac{C_{sécl} * n_{écl} * \Delta t}{24} \quad (5)$$

Where $Q_{sécl}$ represents the heat gain from lighting, based on the number of lamps ($n_{écl}$), their total operating time (Δt), and the sensible heat ($C_{sécl}$) depending on the lamp type.

3.1.3 Gains from Machines or Electrical Equipment

These gains are calculated using the following formula:

$$Q_{mach} = \frac{N_m * t_m * Pm}{24} \quad (6)$$

where Q_{mach} represents the heat gain from machines, calculated using the number of electrical machines (N_m), their operating time (t_m), and power rating (Pm).

3.1.4. Total Internal Heat Gains

The total internal heat gain is the sum of the gains from occupants, lighting, and machines:

$$Q_{int} = Q_{occ} + Q_{sécl} + Q_{mach} \quad (7)$$

3.2. Quantification of External Heat Gains and Thermal Load in HVAC Systems

The thermal load of air conditioning mainly depends on external heat gains. These gains come from heat transmission through walls, roofs, floors, and glazing. The amount of heat transmitted is calculated by the formula:

$$Q_{str} = U \times S \times \Delta\theta \quad (8)$$

where U is the thermal transmission coefficient, S is the surface area, and Δθ is the temperature difference.

Solar radiation also contributes to heat gain, especially on walls and windows. This radiation is partly absorbed depending on the color and nature of the surfaces. The heat absorbed by solar radiation on a wall is calculated with:

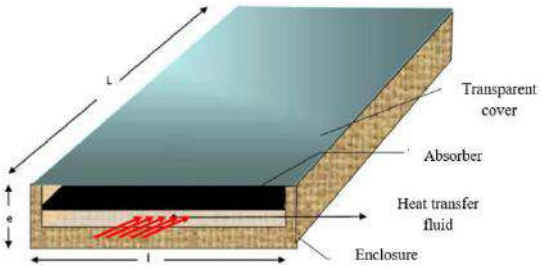
$$Q_{sRm} = \alpha * F * S * Rm \qquad (9)$$

where α is the absorption coefficient, F is the solar radiation factor, S is the surface area, and Rm is the solar radiation intensity.

Furthermore, air renewal and infiltration bring sensible and latent loads into the air-conditioned space. These loads increase the required power of the air conditioning system. The sum of sensible and latent loads forms the total thermal load to be compensated. Therefore, controlling these heat gains is essential for properly sizing an air conditioning system in a tropical climate.

3.3. Solar Air Collector Principles and Performance Factors

Solar thermal collectors capture solar radiation and convert it into usable heat energy. A solar collector transforms free and available solar energy into heat or electricity. It transfers this energy to a heat transfer fluid, such as air or water. Various types of solar collectors exist, including unglazed flat-plate, glazed flat-plate, vacuum tube, and concentrating collectors. Unglazed flat-plate collectors operate at low temperatures and are mainly used for pool heating or preheating water. Glazed flat-plate collectors are the most common and are used for domestic hot water production, with typical temperatures below 70°C. Vacuum tube collectors provide high efficiency at elevated temperatures and are used for industrial hot water or steam production. Concentrating collectors focus solar radiation using reflectors to generate electricity. Flat-plate air collectors use air as the heat transfer fluid and are suitable for space heating applications. For this project, a flat-plate air collector was selected to heat an indoor space efficiently and economically.



Figure

The working principle of a solar air collector is based on the greenhouse effect. Solar radiation passes through the transparent cover and heats the absorber, which then emits infrared radiation that is trapped inside the collector. This absorbed energy increases the temperature of the material and is transferred to the air by thermal contact. The performance of the collector depends on external parameters (solar radiation, ambient temperature, wind speed) and internal parameters (geometry, fluid flow rate, and material temperatures), [13].

3.4. Orientation and Tilt Optimization of Flat-Plate Solar Collectors

The flat-plate solar air collector must be installed in a fixed position with optimized orientation and tilt, depending on the location and the intended operating season, to maximize energy collection, [14]. In practice, and depending on the intended use of solar energy, the following rules are applied:

The collector must be placed in a location free from shading obstacles that may block solar radiation from reaching the surface.

Orientation and tilt depend on the geographical location, specifically the latitude and longitude of the site.

In Analamanga, the collector orientation is the same as that of bioclimatic buildings in Madagascar, facing North-East. The tilt angle is calculated based on the latitude, and it is given by the following formula:

$$\theta = \Psi \pm \delta \qquad (10)$$

Where θ is the tilt angle (°), Ψ is the site latitude, and δ is the solar declination (starting from 23° in our country)

3.5. Electric Heating Integration and Thermal Regulation in Solar Systems

The electric heating resistor heats indoor air during low solar radiation and at night. It is coupled with an electric fan, which prevents condensation in electrical components and ensures homogeneous air distribution. Thus, it provides both warm air and good air circulation to maintain thermal comfort. The regulation system controls the airflow needed in the building and supports the solar heating system. The underfloor heating distributes the collected solar heat through a copper serpentine tube using a heat-transfer fluid. Temperature is then measured at various points, including ambient air, solar collector, and heat-transfer fluid inlets and outlets, using a probe thermometer.

IV. RESULTS

4.1. Thermal Data Analysis and Power Calculation of Solar Air Collectors

The efficiency of the solar collector and the useful power of the air conditioner depend on the temperature measurements from the collector and the heating resistor temperature. Weather conditions during the test period influence the results. The experiments were conducted over a period of 7 days, with a time interval of 60 minutes. Tests were carried out from 6:00 a.m. to 5:00 p.m.

The following temperatures were measured:

- Glass temperature (Tv)
- Absorber temperature (Tab)
- Outlet fluid temperature (Tfs)
- Inlet fluid temperature (Tfe)

All recorded data during the test period are presented in Annex 1. The temperature of the heating resistor was maintained at 35°C. A sample of the results is shown in the following table 3:

Table 3 : Sample of the results during the day 10/11/22

Date	Hour	T_v °C	T_{fs} °C	T_{fe} °C	T_a °C	Humidity %
10/11/22	6h	28	30	19	18	50
	7h	29	30.8	20	18.5	45
	8h	30	31	21	19	42
	9h	32	34	22	21.5	42
	10h	36.8	38	24	22	42
	11h	39	41	25	21	42
	12h	41	43	25	21	42
	13h	40.8	42	24.5	20	42
	14h	39.5	41.8	24	20	42
	15h	38	41	23	19.5	42
	16h	37	40	22	18.5	42
	17h	33	39	22	18	43

According to these results, the power of the solar collector can be calculated, as it depends on the outlet and inlet temperatures of the heat transfer fluid. Based on Equation (48), the calculated power is 356.125 W. The data results are also presented in graph form using MATLAB software. Temperatures are expressed in degrees Celsius (°C).

The following results show the air solar collector temperatures, including:

Outlet temperature of the heat transfer fluid

Inlet temperature of the heat transfer fluid

Ambient temperature of the air-conditioned room

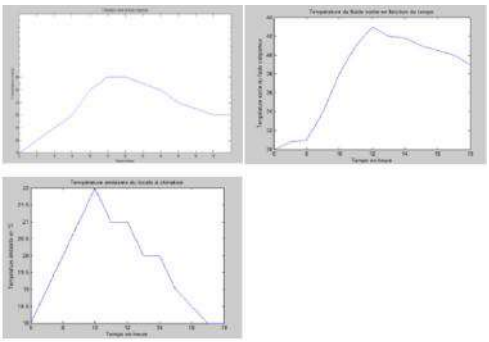


Figure:

All heat gains in the building are identified and classified as internal or external. Internal gains depend on the operation time of equipment and the presence of occupants. External gains depend on the thermal transmission coefficients of the building envelope. The total heat gains are equal to the power of the installed air conditioner. Solar collector temperatures and comfort temperatures vary with local weather conditions. Heating is needed in the morning and evening, and cooling is needed at midday. Heating is provided by the solar collector,

and cooling is ensured by natural ventilation and air infiltration. The energy systems, including battery, solar panel, and controller, must be properly sized to meet daily thermal needs.

4.2. Coefficient of Performance and Power Assessment in Heating Systems

The coefficient of performance (COP) represents the efficiency of the heating system and has no unit. It is essential for heating system installation and plays a key role in the profitability of the device. COP is calculated as the ratio between the heat produced by the solar collector and the energy consumed to produce it. In this project, COP = 2, which indicates good efficiency and low energy consumption.

$$COP = \frac{Q(kWh)}{W(kWh)}$$

The power of the air conditioner can be determined to avoid under-sizing, excessive energy use, and unnecessary economic cost.

$$P_{annual} = \frac{(612\ .01\text{W}\times 12\text{h}\times 360)}{1000} = 2643.8\text{kWh/year}$$

V. DISCUSSIONS

According to the results, the inlet and outlet temperatures of the heat transfer fluid can be used to heat water. This means the solar collector is capable of producing domestic hot water. Madagascar has a warm climate during the summer, so the heating system is not required during this period, as natural heat is sufficient. The solar collector can therefore be used to heat water in summer and to produce space heating in winter. In this study, the collector was tested for water heating, and it can heat 20 liters per hour. A solar thermal tank is required to store the hot water. The most suitable and easy-to-install storage system is the thermosiphon solar tank. The domestic hot water demand depends on the user, so the collector size, coil diameter, and storage tank surface must be increased for higher water consumption.

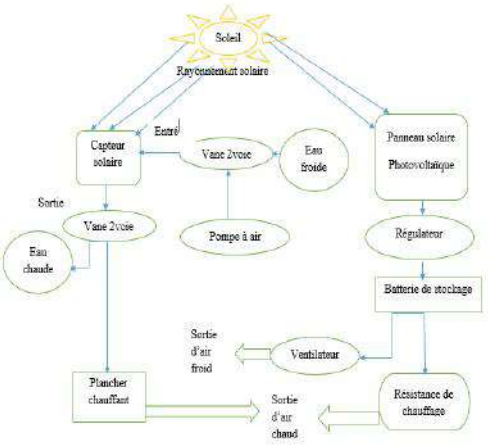


Figure:

Madagascar is located in a tropical zone, which is suitable for using a solar air heating system for buildings. This system is cost-effective and economical, as all construction materials are locally available and easy to install. According to Table 11, the total cost of the solar and heating installation is 499,000 Ar.

In comparison, conventional air conditioners in Madagascar cost between 1,500,000 Ar and 3,000,000 Ar and require monthly electricity payments, making the proposed system more economical and profitable.

VI. CONCLUSION

This study demonstrates that solar air collectors can effectively meet heating needs in tropical climates like Madagascar. The experimental results confirm that the system provides sufficient thermal power to ensure indoor comfort during cooler periods. The collector operates efficiently with a COP of 2, indicating good energy performance. Furthermore, it allows dual use for both space heating and domestic hot water production.

The system proves to be simple to install, low in maintenance, and cost-effective compared to conventional air conditioning units. All materials used are locally available, which facilitates replication and scalability. The integration of solar energy into building thermal regulation reduces energy bills and environmental impact.

In conclusion, the hybrid solution combining solar air heating with basic ventilation offers a sustainable and affordable alternative adapted to

tropical conditions. This approach contributes to energy transition goals while improving living conditions in warm regions.

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Strategic Sourcing of Fashion Accessories: The China plus-one plan for a pureplay fashion retailer

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Introduction

Ravi Sen, on his way to the office was going through the newspapers where a report elaborately discussed the "Vocal for Local" campaign and another one where a local politician sought a ban on Chinese goods. Mr. Sen for a while did wonder whether it was even possible for anyone to boycott China or for that matter any other nation that leads in manufacturing by nothing less than a lion's share? Was it possible to boycott Chinese manufacturers without compromising either on price or on quality or on both? It left him wondering about the future of sourcing his lifestyle accessories brand "Abot", which was predominantly manufactured in China. The decision to manufacture in China had not been taken in a hurry, he remembered. China excels not only in the final product but also in the raw material and parts supply ecosystem. Hence, shifting a significant sourcing volume to India or that to any other nation, he surmised, was as difficult as transplanting a full-grown tree, if not more. He will be discussing this with his sourcing team today.

Onshoring Handbag Manufacturing: A Background

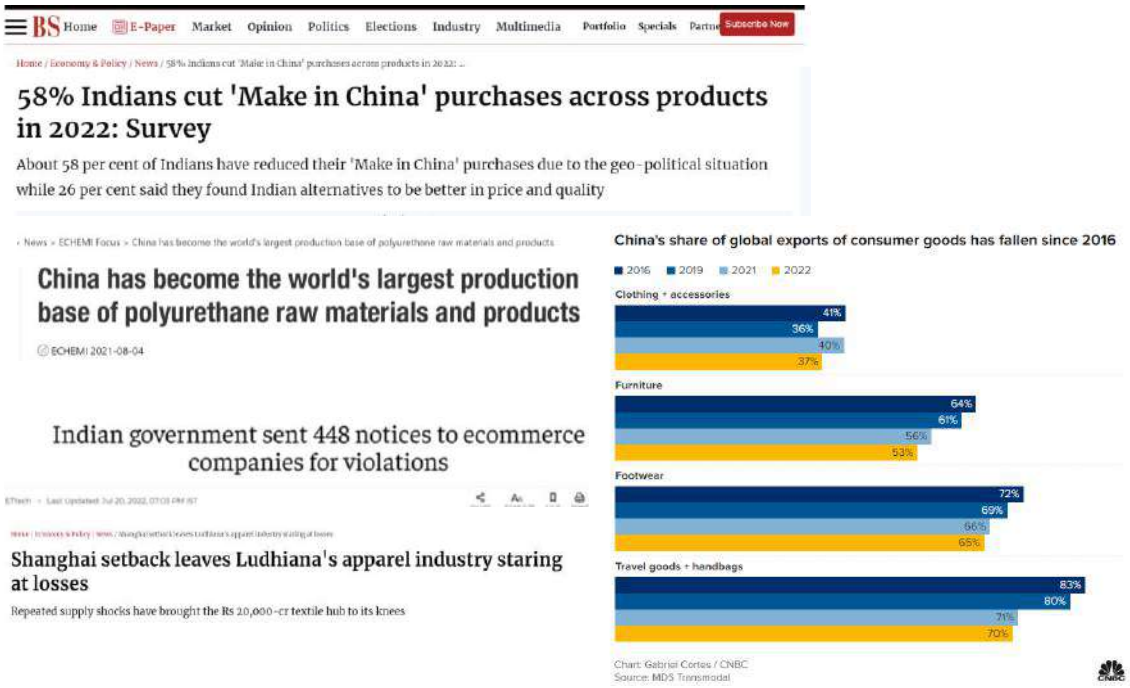
India could well become a global sourcing hub for PU leather goods and accessories. The availability of skilled craftsmen, adept at working with leather could pave the way for enhancing the country's share in the global leather goods and accessories segment. India is the fifth largest exporter of leather goods and accessories in the world. Its share in the global leather goods and accessories segment is between 5% to 6%. India is the second largest exporter of leather garments, 2nd largest exporter of Saddlery & Harness and 5th largest exporter of Leather Goods in the world. The annual availability of leather in India is about 3 billion sq. ft. The major markets for Indian Leather & Leather Products are USA with an approximate share of 23.77%, Germany 11.00%, UK 9.37%, Italy 5.91%, France 5.72%, Netherlands 4.45%, Spain 4.36%, China 2.80%, Poland 1.69%, Belgium 2.37%, UAE 2.16% and Hong Kong 1.40% (Council of Leather Exports, 2022). Most of the manufacturing units for leather goods are located around cities like Kolkata, Chennai, Mumbai, Kanpur, Bangalore and Puducherry in India.

Despite the potential that India holds in manufacturing leather bags, it suffers a significant downside in polyurethane handbags. A major percentage of PU handbags are being imported from China. The reasons are not difficult to understand. Indian brands appreciate the speed at which Chinese PU bag manufacturers translate designs to prototypes to final shipment. Apart from the professionalism, China has an advantage of the economies of scale, a scale which is unthinkable in the Indian market conditions. China also leads the way in PU bags due to new and improved technological innovation which has reduced cost of manufacturing PU leather. In addition, the upstream supply linkages further combine the synergies expected of this potent concoction that makes an indomitable supplier base.

India is a country with a huge young working age population. This necessitates creation of gainful employment for its youth. Hence, given the strong

conservative pull towards reshoring, Indian businesses have been compelled to diversify their supply base. Most of the companies are busy developing a regional strategy of producing a substantial proportion of key goods within the region where they are consumed (Shih, 2020). This also helps them eliminate the need for custom duties on imports of handbags. Overall consumer sentiment in India is to buy locally produced goods and it is only getting stronger.

Exhibit 1: News coverage on consumer sentiments and the Indian industry's dependence on imports from China



Besides, many Indian brands are considering reshoring their operations to India given the focus on Government of India's make-in-India campaign and Production Linked Incentive (PLI) schemes. With such initiatives, the overall manufacturing eco-system in India is undergoing a massive change.

Research literature also supports this stance on the Government of India. Palit, Hora & Ghosh (2022) recognise that one of the critical challenges of technology management for a firm is managing technological knowledge. They focus on available technological knowledge in a firm's global supplier network and examine factors that accrue innovation benefits from such knowledge for a buyer firm. The findings confirm the negative association between technological distance and innovation performance and the positive association between technological breadth and innovation performance. Contrary to expectations, technological distance plays a negative moderating role in the relationship between technological breadth and innovation performance. (Jung, 2020) assesses the onshore and offshore supply bases for buyers facing competition and supply and demand uncertainty. The results show that risk pooling is an essential driver in supplier selection in that the need for dual sourcing cannot be eliminated by other influential factors (e.g., responsiveness and competition effect). However, firms may suffer from a dual-sourcing option under competition. This contrasts with the conventional wisdom that dual sourcing benefits firms in the presence of supply uncertainty. Regarding order allocation, market responsiveness is not necessarily an order winner since it does not lead to a larger order to an onshore supplier if demand is guaranteed above a certain level. (Berry & Kaul, 2015) have put forward a theoretical account of firm global sourcing decisions, distinguishing the antecedents of offshore integration from those of offshore outsourcing. Although traditional theories of global sourcing focus on lowering costs, they argue that as high-performing firms seek to develop new capabilities by tapping into foreign knowledge, they will increasingly turn to offshore integration to reap colocation benefits and overcome expropriation challenges. By contrast, offshore outsourcing will be preferred by less

profitable firms seeking to tap into low-cost inputs, especially as investments in information technology lower monitoring costs.

Considering the above, Indian companies find some value in onshoring of their operations to capitalise on the unceasing Made-in-India sentiment as well as to realise benefits accrued from the synergy between technological innovation, market responsiveness and technology management.

Background: Company and Product

Mr. Ravi Sen's company RAPL started its operations in 1984 and established its reputation as a trustworthy name in the world of fashion apparel and accessories in India for men, women and kids. It is one of the leading pure-play fashion retailers with a retail space of around 10 million sq. feet and a turnover of around 11,000 Cr. The company has a strong network of more than 2000 brand stores across the country. It is present across around 30,000 multi-brand outlets in India. Besides it has exclusive partnerships with some leading international brands and strategic partnerships with several leading design houses. The company boasts a bouquet of 11 private labels that have now become a household name across the country.

RAPL's portfolio includes over 25-year-old brands such as Abot, Margerie, AS, etc. Although these brands are most famous for their clothing lines, they also manufacture accessories and footwear. They have recently been performing very well in the handbag segment and are known for making stylish PU handbags. Being a vegan brand, they avoid using actual leather and instead use faux leather or PU leather.

These women's handbags supplement the brand's power clothing approach. The offerings include 2-in-1 reversible bags with distinct colours on each side and a detachable interior pouch, convertible bags with an extra changeable flap, and brand monogram totes, satchels, and wallets. The starting price range for bags starts at Rs. 1499, with prices ranging from Rs. 1499 to Rs. 3499. Usually, every woman prefers to carry all essentials with her throughout the day, whether at the office lunch or on a night out. "These bags are the ideal combination of form and function for fashion bags for 'every woman - every time'. Each bag is carefully crafted to complement the sharp aesthetics of the women's collection, whether it's fusion formals, day casuals, fusion, or evening collections."

Presently, only two brands under RAPL namely, Abot and Margerie are offering fashion accessories like women's handbags. This category has performed extremely well with around 5 per cent CAGR in the last three years. Within the handbag's product profile, both brands include shoulder bags, tote bags, hobo bags, handheld bags, sling bags and satchels. The brands sell shoulder bags and hand-held bags followed by satchels and sling bags.

The pricing for the handbag segment in both brands is similar. The difference in prices within the same product type could be observed based on size (larger size has higher prices), style (formal or casual) and additional functionality in the design. Overall, the price range for Abot for handbags is observed at Rs.1,399-3,799 and for Margerie, it is observed to be Rs.1,299-3,999.

Exhibit 2: Product Pricing

Product Type	Abot	Margerie
Shoulder Bag	Rs. 1,399-3,799	Rs. 1,999-3,999
Handheld Bag	Rs. 1,399-3,799	Rs. 1,799-3,599
Sling Bag	Rs. 1,799-2,899	Rs. 1,299-2,599
Satchel	Rs. 1,799-3699	Rs. 1,999-3,599
Hobo Bag	Rs. 2,299-2,899	Rs. 2,299-3,599
Tote Bag	Rs. 2,599-3,499	Rs. 2,299-3,599

(Authors work)

The material used for these handbags is usually Polyurethane Leather (PU Leather), with very few instances of other kinds of synthetic leather, fabric and polyester. The handbags for both brands could be generally noticed to be firmly structured, the various shapes involved are regular firm solid structured baguette handbags, bucket handbags, half-moon shaped, slouched structures (hobo bags), basket-shaped bags, etc. Their surface manipulation spans from solid colours to various textures and detailing. The numerous kinds of textured surfaces could be distinguished as animal textures like croc, snakeskin, geometric textures; checked textures; striped textures; Saffiano textures; basket weave textures, etc. Other contemporary surface experiments include cut and work detailing, applique detailing, embellishment detailing, thread-work detailing and quilted and

embroidered details. Prints on the handbag surface are those of geometrical and floral patterns. Alongside solid colours, tie and dye effects, colour blocking, printed (floral, typography, graphic, abstract etc.), glossy finish, etc. are also widely used in the products. The handbags are made in a wide variety of colours. They can be made in any colour, be it staple classic colours like brown, burgundy, black, white, off-white, beige, tan, navy blue, mustard, grey, etc. or other more vibrant colours like red, pink, purple, coral, mauve, lavender, yellow, teal, turquoise blue, olive green, sea green, mint green, rust, peach, maroon, chocolate brown, taupe, nude, khaki, silver, etc.

There are various types of closures for instance zip closure (most common), magnetic button closure, buckle closure (at times having detailing on the buckles), push lock closure, tuck-in flap closure, drawstring closure and twist closure. The additional elements that can be noticed are tasselled details, fringed details, and many more. Various other details like detachable straps, both double and single handles handbags and metal handles whereas some functionalities attached were key hooks, detachable zip pouches, multiple pockets, card holders, pen organiser, mobile pouches, tablet and laptop sleeves (up to 12 and 16 inches) and padded laptop compartment. All of the closures and metal accessories are sourced from China.

All in all, the handbags are a segment that RAPL would like to not only stay invested in but aggressively pursue, considering the 5 to 7 per cent CAGR that the category promises.

Raw Material as Kingpin: The curious case of PU leather

In 1963, Dupont created PU synthetic leather (brand name Corfam), which has a comparable appearance and feel to natural leather (Lu et al., 2021). PU leather has a similar feel and appearance to leather but does not require the use of animals. 100% PU leather is a synthetic material that is made without the use of animals. The most typical method for making PU leather is to put a plastic polyurethane cover or a polyurethane coating on a fibre substrate (generally polyester or rayon). The PU leather can be blended with genuine leather to create "bi-cast" leather. A basis of divided actual leather can be used in the "bi-cast" leather, which is then covered with a PVC or PU layer. It has the same texture as animal skin (genuine leather), but it is usually lighter. That's why artificial leather is also known as bi-cast leather, split leather, reconstituted leather, bonded leather, etc.

PU leather is less durable than real leather, and it tears readily. On the positive side, it is more UV resistant, which is why it's commonly used to cover automobile seats and faux leather furniture. PU leather, unlike genuine leather, is not as breathable. It is, nevertheless, more breathable than other synthetic leathers like PVC.

The APAC(Asia-Pacific) region can be seen as a growing base for the synthetic leather industry. The major producers are from China, Japan, Korea, Taiwan, India, and Italy. Other than them, Indonesia, Bangladesh and many other countries produce synthetic leather (Innovision Consulting, 2020).

Factors such as augmented demand in the automotive and footwear industries, increasing penetration of PU synthetic leather materials, and increasing investments by foreign players in the footwear industry will offer immense growth opportunities in the synthetic leather market in India. However, factors such as the harmful effects of PU and PVC on humans may threaten the growth of the market. The polyurethane artificial leather market in India is characterized by the presence of small- and medium-scale manufacturers. A growing interest in PU leather has been evident in the Indian Polyol and Polyurethane manufacturing industry since 2017 (Business Standard, 2017). Many new ventures, including joint ventures between international companies, have set up manufacturing capacities in India looking at the synthetic leather trend in India (Business Standard, 2022). Research suggests that in 4-5 years, 100 per cent of the growth in the synthetic leather market will be accounted for by India (Exhibit 3)

Footwear emerged as the largest application segment and accounted for over 34% of the total market revenue. The price of PU leather footwear is three times cheaper than footwear made from animal hide, which enables large-volume purchases, particularly from middle-income groups.

Exhibit 3: Synthetic leather market growth (Technavio, 2022)

Topline Commodities Pvt. Ltd., a Kolkata-based company set up a unit of PU leather in Dahej in the state of Gujarat about two years ago with an initial production capacity of 10 million metres annually. Final findings in the anti-dumping investigation concerning imports of "Polyurethane Leather which includes any kind of textile coated one-sided or both sided with Polyurethane" originating in or exported from China PR, according to an anti-dumping investigation initiated by the Directorate General of Trade Remedies under the Ministry of Commerce and Industry, dated 21st February 2022 has highlighted the gaps in the industry, besides other things. The applicant M/s Topline Commodities Private Limited alleged the dumping of Polyurethane defined as "Polyurethane Leather which includes any kind of textile coated one sided or both sided with Polyurethane" by China. The DGTR in their findings, inter alia, has observed, "The major cost of production of the petitioner (*Indian Manufacturer*) constitutes raw materials as minimal value addition is required for coating i.e., the manufacturing process performed by the domestic industry. It cannot be in the public interest for the Authority to impose an anti-dumping duty to protect a domestic industry which performs a minimal process and deals a death knell to the entire downstream industry whose value addition is much higher and which employs a far greater number of people across the diverse industries in which the PUC is used and which consist primarily of MSME's." Chinese manufacturers have been able to reduce PU manufacturing costs by around 25 per cent on account of a new technology called Dry Process, where they do not need to undertake the coagulation step, goes to show that research in this area can help Indian manufacturers also reduce their raw material costs. It is also clear that the battle for supremacy over PU leather is far from over.

Objective:

To devise a sourcing strategy where at least 80 per cent of the fashion accessories for RAPL are procured from an Indian vendor base. This would entail a thorough investigation of the existing offerings and how the company will need to deviate from them to localize the vendor base while also maintaining its brand identity.

Background: Indian Handbag Market

India's handbag market is highly fragmented and most of the players rely on product innovation to sustain the high competition. There were multiple players in the market including Baggit, Capri Holdings Ltd., Da Milano Leathers Pvt. Ltd., H & M Hennes & Mauritz AB, Hidesign, Kering SA, Lavie, LVMH Moet Hennessy - Louis Vuitton, The House of Tara, VIP Industries Ltd., etc. For the five years 2021-2025, the handbags market in India was expected to grow by $ 207.51 mn, growing at a CAGR of around 5% in the given duration (Technavio, 2021). In other words, a lot of growth could be seen in the industry in the Indian market. The leading brands made long-term capacity plans and dedicated vendor tie-ups to tap into this lucrative market. The handbag market is divided into leather and non-leather bags, where Abot

and Margerie are competing in the non-leather polyurethane-based product. Where such products are not only more competitive than leather products but also, could reap better margins for the company given the design capabilities of RAPL. China and Myanmar have emerged as the leading sourcing bases for polyurethane bags, especially so with China (Su & Gargeya, 2012). Not only did China lead in the production capacities in terms of quality, technology, and finesse, but also it developed an eco-system that synergized the capabilities of each of its constituents to a multi-fold. China was not only the major Polyurethane supplier but the buckles, buttons, and metal parts were also a part of China's manufacturing armour. Hence, the leading Indian brands found it easier to source products from Chinese suppliers vis-a-vis their Indian counterparts. RAPL had been able to secure 80 per cent of apparel sourcing from India, but the non-leather women's handbags were still being sourced from China.

The key issue:

With a significant proportion of Indians being under the age of 35 years, the Indian market was promising and the Indian office-goer was eager to welcome accessories that matched her dapper clothing. Abot and Margerie held a significant share in the Indian fashion retail sector and they specialized in women's handbags. But RAPL was competing against the likes of Lavie, Hidesign, Baggit, Capri Holdings Ltd., Da Milano Leathers Pvt. Ltd., H & M Hennes & Mauritz AB, Kering SA, etc. to name a few.

Many of the competitors were focused on bags, they made only bags. Hence for Abot, to compete in a market where it was competing with niche brands was easy and difficult. It was easy as RAPL brands and legacy had strong visibility given the reach of the parent company in so far as physical locations were concerned. On the other hand, it was difficult as the customer while browsing products online had the luxury of comparing the RAVISSON APPARELS PVT LTD products with those of niche brands. Thus, the company was competing in an extremely price-sensitive market. But Mr. Ravi Sen knew that sooner or later they would have to reduce their dependence on China and diversify their sourcing base for bags. He had his reasons to do so.

Another concern was that the consumers today would like to know where their product comes from. The "Vocal for Local" campaign has also gained substantial strength in India. But today brands are attempting to mitigate the danger of tariff barriers imposed by the government against China. "Consumers want to know where their products come from, and there's a lot of interest in what is made in India right now," he said (Economic Times, 2022). The "Vocal for Local" campaign has attracted a lot of attention, and people are starting to think about where their products are made before they buy them (Mukherjee & Bailay, 2022).

Deliberations for future strategies

After thorough research, the committee geared up for a detailed presentation for the assignment in question. This research was based on the costing of identified designs of comparable quality received from Indian and Chinese suppliers (Karami, Yaghin, & Mousazadegan, 2020). As the quality of the handbag was a constant, a comparison of costs was drawn as shown in Exhibit 1.

Exhibit 4: Components of cost as a percentage of total cost per bag

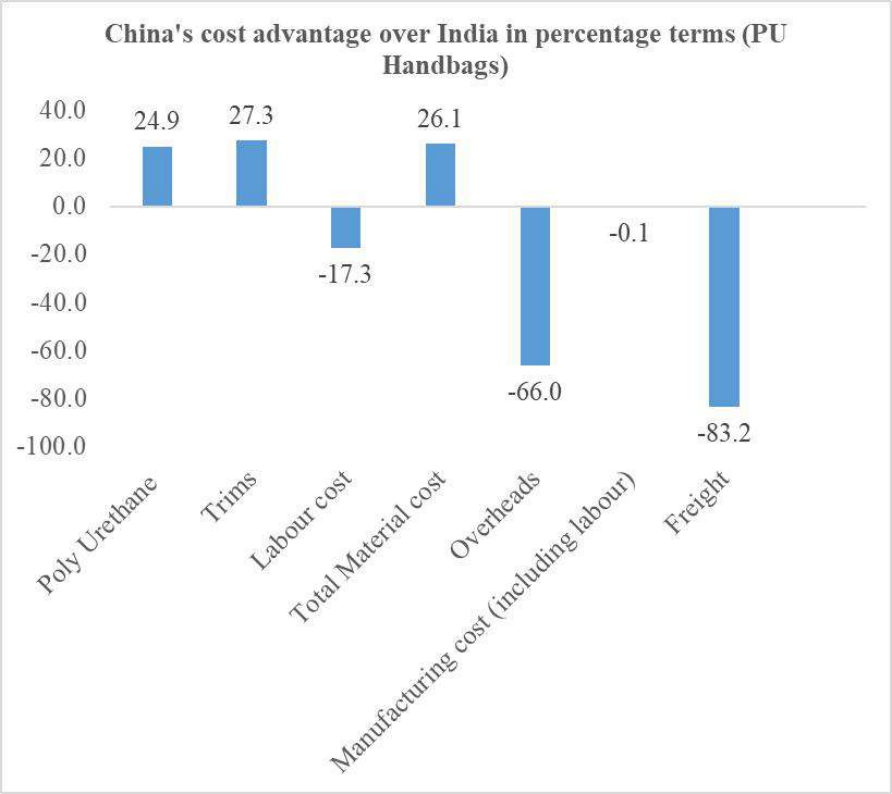
	% of total cost in India	% of total cost in China
Material	30.5	22.1
Trims	19.3	13.8
Labour cost	16.7	18.3
Cost of Manufacturing	73.9	67.0
Total Material cost	50.9	36.6
Overheads	2.9	7.7
Freight	1.7	9.3

(Authors work)

When compared to China, India was a cheaper sourcing base in terms of freight and labour costs and it was observed that raw material costs in China came out to be cheaper by around 20 percent. However, India was cheaper by 33 per cent in terms of labour cost. Major savings could be realized from freight charges where the total levy on China made it around 19 times more expensive than India. Other aspects to be considered were the duties on the handbags which were around 18 per cent, whereas in India this could be a direct saving.

The team also evaluated the cost competitiveness of India vis-à-vis China as shown in Exhibit 5. This included the study of various parameters including material and trim cost, labour, overheads, etc.

Exhibit 5: Competitive advantage of China over India (PU Handbags) (Authors work)



As shown in Exhibit 5, China has enabled the factors of production much more efficiently than India. As can be seen, the raw material (PU) and trims cost is lower in China by around 24 per cent to 27 per cent. The team elaborated that the total cost of manufacturing a bag in China and India was almost the same, as the cost benefits accrued to China in terms of the PU material and trims are offset to a certain degree by its increasing labour cost and higher overheads. The deciding factor thus is the freight charges and the customs duty on PU handbags in India. With an additional 83 per cent tariff on the handbags made in China, the team demonstrated that the levies were a major deterrent to sourcing from Chinese suppliers. This was not all, even the lead time for the PU handbags made in China was at least 33 per cent longer than that taken by their Indian counterparts for fresh orders, while for replenishment orders it was around 50 per cent longer than Indian suppliers, of which transit was the major component.

Mr. Ravi Sen started deliberating on the implications of the study undertaken. He said, "While I understand that we do not have the most favourable PU handbag eco-system in India, can we develop it, on whatever scale that we can, how can we develop this eco-system? Can you take this up, Mr. Chopra? We need a Supplier Development Roadmap for PU and other raw materials.

Review and Future Strategies:

A major turnaround was due to the outcome of research by the sourcing team. In a review meeting attended by department heads and their respective teams, Mr. Ravi Sen stated, "The company can apply

a multi-pronged approach here. Given that the dependence on China is significant and cannot be completely substituted by the Indian suppliers, a plan to phase out the dependence can be made. Introducing a supplier development program to develop a complete product package for the company was a good idea. There is a scope for creating a joint design and development lab for the product in partnership with the key suppliers/fabricators. While it is difficult to match the advantages of the Chinese manufacturing capabilities for Indian suppliers, given the scale of manufacturing that China undertakes, it is important to realize that the infrastructural gaps in the value chain can be plugged by government intervention in common utilities. I am sure our research wing can come up with a white paper for the industry to make our needs clear to the Government. A handful of players in the Asia Pacific are primarily dominating the PU and artificial leather market. The company can get into strategic knowledge-sharing agreements with the leading companies and involve them in the design and development of products for India. In all the company will need to devise a framework for the development of a streamlined value chain for PU goods in India. Partnerships with key suppliers in India and others in the Asia Pacific will remain the mainstay. Besides, the investment made in developing such a value chain will pay off multi-fold as it will support multiple products made of artificial leather. Government support in this sector can be assumed as it will be eco-friendly and will cater to multiple industries like fashion, automotive, travel accessories, etc. With this, I conclude this meeting”**.** Ravi Sen pondered over the future challenges and opportunities for the company, as he proceeded for his next meeting scheduled with a leading Indian vendor of PU handbags.

Note: The name of the main organization, protagonist and related key figures have been masked to maintain confidentiality.

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Strategic Sourcing of Fashion Accessories: The China plus-one plan for a pureplay fashion retailer

Teaching Note

Abstract – *Ravisson Apparels Pvt ltd (name masked) is a leading pure-play fashion retailer in the Indian fashion retail landscape. Ravisson Apparels Pvt ltd (RAPL) sells a range of products including apparel and lifestyle accessories for men, women and kids. RAPL is sourcing most of its vegan leather handbags from China. This case is based on the challenges faced by the company as it contemplates shifting the manufacturing base of its vegan leather handbags to India. Given the supply chain challenges faced by the company due to COVID-19 in addition to the fact that the "Make-in-India" movement has gained strength among Indian citizens in recent years, RAPL would like to shift at least 80 per cent of its handbag sourcing to India. Currently it sources only around 10-15 per cent of its handbags from Indian suppliers. The company conducts a comparative analysis of Indian and Chinese vendors while thoroughly examining the challenges involved. A team of 10 sourcing managers is formed to study the methodology of reshoring the production of PU handbags to India. A report submitted by the team leads the light on the homework to be done before undertaking this massive change in sourcing strategy. The team compares suppliers from India and China on several parameters including material and trims cost, labour cost, manufacturing cost, overheads, freight and intangible factors like design language, supplier development, etc. The study shows that the answers to the vexing questions the company faces are not so straight forward and many externalities are involved.*

The team realises that the gap between the aspirations of the Indian consumer, the readiness of the indigenous sourcing networks and the value perception is wide. In this process, the company realizes that significant long-term shifts are required in the existing outsourcing strategy.

Target Learning Group:

This case was used twice with semester VII students studying Global Procurement and Sourcing in the course Bachelor's in Fashion Technology at National Institute of Fashion Technology, Gandhinagar. The students have a theoretical background in operations strategy-especially apparel operations and Indian Fashion Industry. The case was used somewhere in the middle of the course. As the student grapples with Factors of supplier relationship to be considered: the problem of developing an organic supplier ecosystem in India, they are also faced with the fact that the sourcing imbroglio is not one simple situation, but instead it is a complex combination of multiple problems, beginning from establishing supremacy in developing raw materials, lack of technological advancements in the field, lack of research in developing new alternative processes or new raw materials, lack of financial support to the smaller manufacturers, no last tier supplier visibility, compliance issues, legal issues and many others issues that need to be addressed before one even considers reshoring.

Students approach to the case:

The consumer of RAPL has also come to expect a certain quality, finesse, styling, etc from RAPL. A sudden decision to onshore the operations to India, will not only affect the price points, but also change the overall appeal of the offerings.

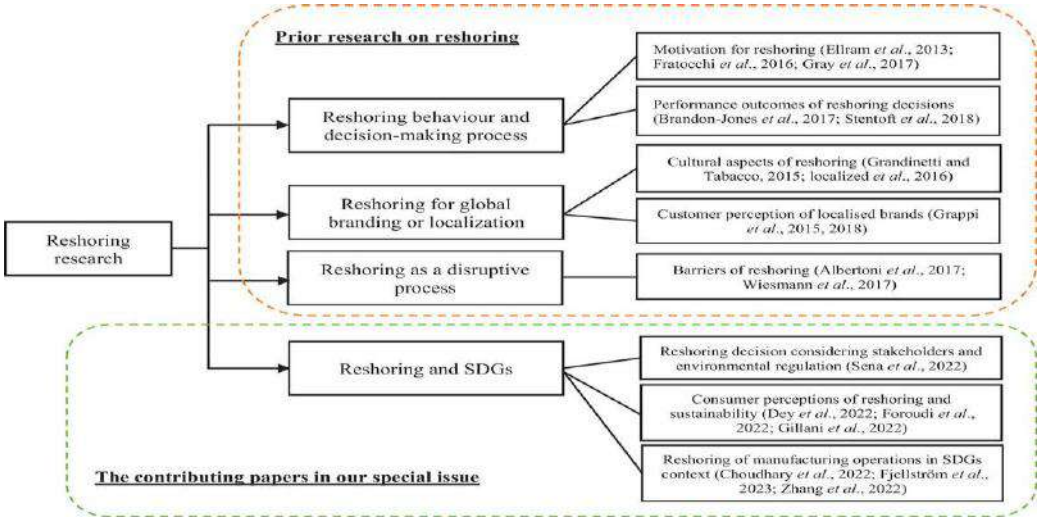
Students who studied this case came out with different solutions and answers to the situation RAPL finds itself in. Students who have studied operations strategy and have a background in fashion studies were essentially perplexed about how Indian manufacturers can be relied upon to help maintain the brand's offerings and the overall brand image. In some of the sessions, they even visited local markets and browsed products on internet to understand the PU bags available from local vendors. Some of the issues reported by the students after primary and secondary research included technical expertise, availability of skilled labour, development of PU in India, logistics cost, supplier relations (SR) and expectation of Indian consumers from RAPL bags and accessories.

It was observed that the Supplier relations are usually not taken into consideration while deciding the factors influencing the supplier evaluation process. Hence, some of these SR factors were noted by Kaplan and Norton in their study and stay relevant to this date as we speak of dedicated supplier partnership, vendor tie-ups, strategic partnerships, etc. (Giannakis, 2007). If a company is to invest in supplier development in India, these factors are even more important that the hygiene factors like technological expertise, quality, etc.

Factor	Points to consider
Trust	Calculated: Actors would only act in a trustworthy manner if it was in their best interests. Cognitive: Arises as a result of shared beliefs among the parties involved. Normative: Characterised by a shared knowledge of the parties' expectations and responsibilities based on industry or society norms (comply with organisational culture, honesty and openness) Trustworthiness is defined as fulfilling promises and having faith in one's relationship.
Power	Responsibility for making choices and issuing instructions is referred to as authority. Control: This stems from the ability to gain access to essential materials that provide context to those who possess them. Influence: An indirect form of power coming from centrality in a network of actors, as opposed to direct power.
Complexity	Complexity: The level of complexity of an SR is referred to as complexity (number and level of individuals involved) Scope: The quantity of resources allocated and the competencies that are transferred between the partners are referred to as the scope. Intensity of interaction: The quantity of information communicated between the parties, the human contact and spatial proximity between the actors, and the early input of suppliers in a customer's projects are all factors that influence the intensity of interaction.
Commitment	Effort: This term refers to the partners' willingness to continue their business partnership. Loyalty: This term encompasses both recurring encounters and attachment to a commercial relationship. SR Length: SR Length: SR Length: SR Le Usually refers to the length of a contract that has been agreed upon.

Table 1: Supplier relation factors to be considered in supplier evaluation process (Giannakis, 2006)

Once we try to look at the literary terrain of reshoring, the following classification comes in handy:



British J of Management, Volume: 34, Issue: 3, Pages: 1081-1099, First published: 10 May 2023, DOI: (10.1111/1467-8551.12731)

Students, on reading this case, often wonder if it is too late for the brand to reshore its operations of PU bag manufacturing to India, they even question if it is wise. At this juncture, it is helpful if the go through some additional readings provided hereunder in order to understand that supplier development and supplier relationships go hand in hand. The roots of the supplier development have been highlighted by Kaplan & Norton in the Balanced Scorecard, despite the criticism it faced from professionals and academics in terms of flexibility, financial metrics, the model still remains one of the most valid and significant management tools (Tawse & Tabesh, 2023). Further the new developments on onshoring after President Trump's conservative focus and relevant policies would help understand that geopolitics affects business supply chains in positive and negative ways.

This case needs an understanding of the Indian fashion industry and that of operations strategy. Additional readings provided with the case will help students to develop an overall understanding of reshoring of operations, how the challenges may be addressed using well known Business strategy models like the BSC, what are the dynamics of the Indian Fashion Retail, and how Indian consumers consume fashion products.

The students with whom this case was discussed were adept at planning for production and were well aware of the technological prowess required to manufacturing a niche product like a PU bag.

Learning objectives:

- To understand the role of deep-tier supplier development in a highly fragmented industry
- To understand the nuances of sourcing strategies with retail firms in focus.

Key Issues:

Fashion and lifestyle accessories retailers are faced with a dilemma when consumer sentiment is at odds with their sourcing strategy, of which pricing is a function. The procurement of the right quality inputs and their best possible assembly true to design is what sourcing is all about. In our case, a significant portion of the handbags are being manufactured in the People's Republic of China. This strategy has worked for the company, but it will work only till it does not. Hence the company must diversify its supply base taking into account the fact that the market for accessories is growing by at least 7 CAGR, and it makes sense to develop a more resilient supply base. With several arguments in favour of reshoring, the company finds it essential to backshore its bag manufacturing operations to India.

Category: Strategic Sourcing, Operations Strategy

Information Source: Field Study

Teaching Plan: The case study will require a minimum of 3-4 hours including the case discussion followed by analysis. In the opening 10-15 minutes, the faculty is supposed to provide the students with a brief introduction to the case. The students may be provided around 30-35 minutes to read the case. The students shall commence the discussion on the predicament facing the company concerning the Indian sentiment on foreign goods. They can discuss technology, suppliers, deep-tier competitiveness in a supply chain, and the overall ecosystem that makes a product globally competitive. The discussion can then devolve to individual insight on how the company can undertake the supplier development program in India. The role of technology transfer, research and development, future strategy on vendor development, the probable financial gains for the company and anticipated support from the Government can be discussed. Students should be encouraged to visit local markets, malls and collect data on the PU bag offerings available in India and their country of origin. Students may also browse internet to find more about PU bag suppliers in India and match their offerings with the PU bags made in China.

Background Reading:

Students may be asked to read the latest news on fashion and lifestyle accessories brands like Allen Solly, Van Heusen, Lavie, Baggit, etc. in order to build a background in fashion studies. It is advised that students make themselves conversant with the offerings of these brands through an online /offline market study. (Khaire, 2019)

Further additional readings for this case

1. Operations Management Research published a Special Issue on "Reshoring: A Supply Chain Innovation Perspective" (June, 2016).
   Relevance: The issue highlights the issues that firms face in "reshoring" or "Back shoring". the papers cover three main areas of investigation for the reshoring phenomenon: conceptualization, motivation, and implementation. Conceptualization mostly pertains to the definition and characterization of the object of study, also in light of the knowledge accumulated in the extant literature. Motivation refers to the identification and discussion of the drivers of reshoring. Implementation is about "how to put reshoring in practice", e.g., based on the decision-making process, or according to the priorities (Barbieri & Stentoft, 2016)
   Relevance: Numerous scholars have highlighted the challenges of reshoring, such as supply chain disruption, labour shortages and sustainability issues, from various perspectives (Gupta, Wang, & Czinkota, 2023). While many authors have suggested that technological advancements will be helpful in addressing these challenges, the authors suggest the new directions where research is still necessary to validate tall claims on how Industry 4.0 will facilitate reshoring.

2. Giannakis, Mihalis. (2007). Performance measurement of supplier relationships. Supply Chain Management: An International Journal. 12. 400-411. 10.1108/13598540710826335.

Relevance: This article explores the performance measurement systems in supplier relationships, offering insights into how firms can better evaluate and manage their suppliers for improved supply chain efficiency. (Giannakis, 2007) identified the Supplier relation factors to be considered in supplier evaluation process

3. Kaplan, Robert & Norton, DP. (2005). The Balanced Scorecard: measures that drive performance. Harvard business review. 83. 172-+.
   Relevance: The **Balanced Scorecard** (BSC) was introduced by **Robert S. Kaplan** and **David P. Norton** as a strategic management tool. Operations strategy as a subset of Business strategy is key to organisational excellence. BSC serves as a backdrop to evaluate, implement any given business strategy.
4. Tawse, A., & Tabesh, P. (2023). Thirty years with the balanced scorecard: What we have learned. *Business Horizons, 66*(1), 123-132. https://doi.org/10.1016/j.bushor.2022.03.005

   Relevance: Provides a thorough critique on the Balanced Score Card and cautions professionals with a central recommendation based on an apparent paradox: While the BSC is a tool for effective strategy implementation, it must itself be effectively implemented to deliver on its potential (Tawse & Tabesh, 2023).

5. Khaire, M. (2019). Entrepreneurship by design: the construction of meanings and markets for cultural craft goods. Innovation: Organisation and Management. doi:10.1080/14479338.2018.1530566

And

6. Khaire, M., & Hall, E. V. (2016). Medium and Message: Globalization and innovation in the production field of Indian fashion. Organization Studies, 37(6), 845-865. https://doi.org/10.1177/0170840615622061

Relevance: Mukti Khaire has written extensively about the Indian Fashion Industry. The above two papers help students to develop an Indian Fashion Perspective.

7. Mangtani, R., Salhan, A., & Rajput, E. (2023). INDIA@100; BUILDING 'ATMANIRBHAR' BHARAT FROM FARM TO FASHION TO FUTURE., (pp. 55-81).

Relevance: The research maps the literature on consumption of luxury products under the 4 major and minor themes viz. (1) Conspicuous Consumption (2) Purchase Behaviour (3) Sustainability (4) Perception and 4 minor themes – (1) Counterfeit (2) Co-creating and Customization (4) Post-Purchase

Behaviour. This systematic Literature Review is based on 67 papers published in the last decade (2012-2023) on consumption of luxury fashion goods in India (Mangtani, Salhan, & Rajput, 2023)

Analysis and Solutions to Assignment Questions:

1. Do you think the strategy of partial phasing out of Chinese suppliers is appropriate? If not, suggest alternative strategies.

In a real-life scenario, sourcing strategies are dynamic. Businesses usually look for long-term commitments. With the current COVID-19 scenario and the sporadic clashes between the two countries on the border, it has become necessary for RAPL to develop a supplier base in India. Over-exposure to any supplier, or nation is also not a good practice in global sourcing. Hence be it China or any other country, the company should be developing an indigenous base at least for the core products. Supplier development and supplier relations are at the core to a healthy supply chain. Back-shoring of operations also augurs well for the overall industrial ecosystem of India. The only aspect that needs to be addressed, which is also one of the most important aspects is the raw material availability, workmanship, competitive pricing, quality. With quality being the same, pricing reduced and lead times halved, the Indian supplier base may be a game changer for RAPL. But over and above the technical and tacit factors are the factors like developing trust, strategic power equations in order to make the strategic partnership last long and contribute to the development of a whole new eco-system.

2. What is a Supplier Development program? How will it help RAPL achieve its objectives?

According to Hanh et al., 2010, the definition of a supplier development program is "any systematic organizational effort to generate and maintain a network of competent suppliers."

In a strict sense, it entails the establishment of new sources of supply when existing suppliers are insufficient to meet the firm's needs. In a broader sense, it also includes initiatives aimed at improving the skills of existing suppliers to satisfy changing competitive demands considered in a broader context, however, the program becomes more proactive and emphasizes continual improvements in suppliers' capabilities for both parties' long-term mutual advantage.

An SDP can be tailored to suit the organization's needs after evaluating suppliers on quality of products, price, labour cost, managerial personnel availability, infrastructure, ease in coordination, delivery performance, organizational maturity, flexibility of the organization, transportation mode, lead times, logistics cost, level of technology, set up costs, product costs, level of customer satisfaction, level of innovation, competitive advantage, rules and regulations, Govt. incentives, taxes, etc. Supplier development and supplier relationship is to be discussed with the important issues faced in reshoring or backshoring.

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The identity of the main company and key figures have been masked.

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Real-Time Intrusion Detection Leveraging Deep Learning: A Comparative Analysis of CNN, RNN, and Transformer Architectures

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Abstract *— Due to the rapid increase in digital data and the rise in sophisticated cyber threats, the demand for smart, automated, and scalable cybersecurity solutions are more essential now than ever. Conventional intrusion detection systems (IDS) typically use signature-grounded or heuristic approaches, which have difficulty identifying new or advanced attacks in live. Recent progress in artificial intelligence (AI), especially deep learning (DL), has unveiled new possibilities in creating adaptive and live threat spotting systems that can learn intricate patterns from extensive flows of network data. This study examines and contrasts the effectiveness of three advanced deep learning frameworks – CNN, RNN, and Transformer models (TMs) – in live intrusion detection within cybersecurity contexts. The research employs benchmark datasets like CIC-IDS2017 and UNSW-NB15, which feature a varied collection of contemporary cyber threats, including DoS, DDoS, botnets, and brute-force assaults. Each model is trained and evaluated with the help of the identical preprocessing pipeline encompassing normalization, encoding, and live simulation of data flow to properly represent the real deployment. The detection performances are evaluated along the accuracy, false rate, precision, recall, F1 score, and inference duration on each event. In addition, special significance is laid on each Model's ability to generalize on unknown attack types and deliver responses within milliseconds, a vital consideration in live detection and prevention. Initial observations point out that while CNNs are proficient in drawing spatial features from static data chunks, RNNs outperform them in time-sequence patterns recognition for time-series network traffic. Nevertheless, the TM fares better in accuracy and in terms of generalization abilities; its self-attention mechanism is at work to capture dependencies efficiently both in short and long ranges without the constraints involved during training of RNNs. Moreover, Transformer-powered Models fine-tuned for low-latency inference present the best compromise between speed and accuracy for live cybersecurity purposes.*

Keywords *— **Cybersecurity, Intrusion Detection, Deep Learning, RNN, Transformer***

I. INTRODUCTION

In the digital epoch, cyberspace has become a crucial infrastructure for the growth of economy and social intercourse globally. From basic systems that oversee power grids, healthcare, and banks to the widespread adoption of personal computing devices, IoT technologies all pervade modern life, and their every facet relies on trustworthy digital networks. The same way that the technology advances, so does the sophistication and prevalence of cyber-attacks. From fresh hackers to government-backed groups, they invent more sophisticated and stealthier techniques that are, in a way, outwitting the usual kinds of

security. This very necessity calls for a more powerful, intelligent, and flexible mechanism that works against any cyber threat. In the many defense mechanisms used in cybersecurity, IDSs play a vital role in detecting and reacting to network intrusions. Earlier, such systems were built with mostly static and rule-based approaches such as signature-based intrusion detection or heuristic algorithms, relying heavily upon pre-established patterns or custom-made rules. The detection techniques will defend against threats they are aware of but cannot catch anew, polymorphic, or obfuscated attacks, especially when an attacker attempts to blend the pattern with those of genuine traffic. Moreover, a present-day network transmission forms bulky data traveling at high speeds, hence taxing traditional intrusion detection methods that, in turn, bring about intolerable latency, high false positives, and delayed reactions.

To overcome these issues, researchers and industry professionals have resorted to Artificial Intelligence (AI), especially Deep Learning, which has changed the perspective toward pattern recognition and anomaly detection. In contrast to traditional algorithms, a Deep Learning model learns complex features on its own through large datasets, with minimum feature engineering being necessary. This ability allows DL-grounded systems to excel at identifying subtle and previously unrecognized behavioral patterns that could suggest malicious actions. In cybersecurity, this means the capacity to identify both recognized and unrecognized attacks instantaneously, improving the overall robustness of information systems. Research on DL utilisation for intrusion detection has surged, with different architectures being probed for their usefulness in practical deployment situations.

The deep learning Model extensively researched in this area include CNN, Recurrent Neural Networks (RNN), and, more recently, TM. Each said architecture has its own set of advantages. CNNs excel at spatial feature extraction and are widely applied to image tasks but also detect patterns in structured network data (e.g., packet headers, flow metadata) for IDS. RNNs, suited for sequential data, capture time-based relationships in traffic that may signal attacks.

TM, initially for NLP, handle long-range dependencies and parallelization, avoiding RNN issues like vanishing gradients and slow training. In cybersecurity, Transformer-grounded methods enable large-scale data handling with strong accuracy, as self-attention highlights contextual relations across activities rather than isolated events. This makes them powerful for real-time, low-latency decision-making.

Despite rapid advances, DL-grounded IDS face challenges—chiefly training data quality and imbalance, as normal traffic samples typically outnumber attack samples. This makes Model biased and makes it hard for them to find attacks from minority groups. Also, a lot of publicly accessible datasets may not accurately reflect the complexity and variability of today's threats, which raises questions about how well the model being developed can be used in other situations. Another issue is adversarial attacks, in which a bad person changes inputs on purpose to fool the detection system. These issues necessitate thorough assessment, resilient and confrontational training techniques, and the integration of strategies to address data imbalance and adversarial resistance.

It is true that computational efficiency is a big problem when utilising DL Model for intrusion detection. Live detection must be very accurate and take as little time as possible to figure out what is going on so that threats can be found and dealt with before they cause any damage. This necessitates the creation of lightweight Model or the enhancement of current architectures through pruning, quantization, or dedicated hardware accelerators. There are also architectural and operational problems that must be fixed to make these Model useful when they are added to existing network infrastructures.

This work aims to systematically assess the performance of CNN, RNN, and TM in live intrusion detection. Utilizing standardized benchmark datasets like CIC-IDS2017 and UNSW-NB15, the work will evaluate the capability of each model to identify a diverse range of attack types in simulated live scenarios. Evaluation criteria will include accuracy, precision, recall, F1, false positive rate, and inference latency. Apart from the performance comparison, the work tries to look into the strengths and weaknesses each model has in changing cyber threats, scalability, and suitability for implementation on real network settings.

Beyond the technical evaluation, the study investigates the real-life implications with Model

application in organizational environments. Issues such as model interpretability, update procedures, and integration with existing security operation centers (SOCs) are addressed to ensure that proposed solutions are not only viable from a technical perspective but make sense from an operational standpoint. These factors will become increasingly critical to understand as an increasing number of companies leverage AI-powered tools for cybersecurity so that they can be applied effectively and remain viable in the long term.

This work looks to enhance the existing knowledge on AI use in cybersecurity and to deliver actionable insights for security experts aiming to utilize deep learning for preventive measures. This study seeks to promote informed decision-making in designing and implementing intelligent IDS systems by identifying the most efficient architectures and their associated trade-offs. Furthermore, it aims to underscore the essential requirement for ongoing learning and model adaptation in an ever-evolving threat landscape, contending that any static Model regardless of its initial accuracy, will inevitably become obsolete without regular updates and retraining.

In conclusion, this research is driven by the necessity for sophisticated, intelligent, and scalable cybersecurity systems in response to the increasing complexity of cyber threats. Deep Learning identifies concealed patterns and autonomously makes decisions, rendering it an effective instrument for enhancing advanced IDSs. This study offers a comprehensive examination of the present and prospective implications of deep learning for live intrusion detection through a detailed analysis and comparison of CNN, RNN, and Transformer architectures. The outcome is anticipated to influence both scholarly research and practical applications, thereby enhancing and fortifying current digital infrastructures.

II. LITERATURE OVERVIEW

Intrusion Detection Systems (IDS)

IDSs are an important factor in net security, designed to identify unauthorized, unusual, or destructive act. Generally, we can divide any IDS into two classes: signature-grounded systems and anomaly-grounded detection systems. Signature-grounded IDS thus use established patterns or rules derived from known attacks, making them highly accurate for known threats but numbly inept against zero-day attacks or sophisticated variants. The anomaly-grounded IDS, on the other hand, track deviations from the set patterns of normal behavior to identify unusual activities. However, said systems generally suffer from high false positives, mainly when the base Model are not properly trained or adaptable to the changing nature of network traffic.

Machine Learning (ML) for Cybersecurity

The drawbacks of conventional IDS have led to significant exploration into applying ML for detecting intrusions. ML algorithms like Decision Trees, SVM, Naive Bayes, and K-NN stand out because they can help find things that traditional rule-grounded methods can't. These Model need labeled datasets to learn from and can adapt to attack patterns yet to be seen, mostly in the area of anomaly detection.

Rise of Deep Learning in Intrusion Detection Systems

Deep Learning, an extension of ML employing artificial neural networks having numerous layers, is increasingly advancing as a promising candidate to answer the challenges faced by traditional IDSs. DL Model generally learn hierarchical representations from raw or slightly processed data, diminishing the meticulous crafting of features over time. It is highly successful in image classification, speech recognition, and NLP. Inspired by these, researchers have explored DL with various cybersecurity applications, especially intrusion detection.

Namely, numerous studies show DL techniques could somehow surpass traditional ML analyses in the recognition of both known and unknown attacks. Their ability to represent complex patterns, time relationships, and non-linear associations makes them excellent contenders for the assessment of dynamic network data and high-dimensional analytics. The DL architectures investigated for IDS include CNN, RNN, LSTM, and, more recently, Model based on Transformers.

Convolutional Neural Networks (CNN) for IDS

CNNs were originally created for image recognition tasks owing to their ability to learn spatial hierarchies using convolutional filters. Within intrusion detection, CNNs are utilised to identify spatial

patterns in network traffic, especially in structured datasets that allow features to be displayed in grid-like formats.

Kim et al. (2016) utilized a CNN model on the NSL-KDD dataset, showing a notable enhancement in classification accuracy relative to conventional ML Model. The network design utilized convolutional layers for deep feature extraction (FE) from input vectors, succeeded by fully connected layers for classification. Al-Qatf et al. (2018) suggested a hybrid CNN-SVM method where the CNN acted as a FE and SVM performed the final classification, producing encouraging outcomes regarding accuracy and computational efficiency.

Recurrent Neural Networks (RNN) and LSTM in IDS

By maintaining internal states that reflect dependencies across time intervals, RNNs adopt a special structure for processing sequential data. Hence, they become more suitable for time-series network data, where each point depends on another. RNNs have found the application of speech recognition and time-series prediction and have lately seen their integration in intrusion detection systems (IDS).

Hochreiter and Schmidhuber (1997) suggested LSTM networks as a kind of RNN that tackle the vanishing gradient problem with memory cells and gating mechanisms. Such LSTM networks for network intrusion detection tasks have been well tested, for example, in studies by Yin et al. (2017), confirming their successful application on the NSL-KDD dataset, For Models show better detection rate and less false positives compared with CNN and traditional ML.

Despite their advantages, RNNs and LSTMs face problems concerning their training speed and scalability. They require fairly great computational power and lots of time to train upon extensive datasets. Markedly, their sequential processing nature disallows any kind of parallelization, thus rendering them less suitable for real-time detection scenarios unless some architectural enhancements are introduced.

Models utilizing Transformers and self-attention mechanisms.

The development of TMs by Vaswani and colleagues (2017) essentially brought about the disruption of sequence Modeling caused by recurrences. Transformers exploit self-attention mechanisms alone to look for relationships among input tokens, thus improving the parallelism during training and inference.

The field of cybersecurity, on the other hand, has a rather young yet quickly growing adoption of Transformer techniques with researchers attempting to use their architecture for IDS with good results. Wang et al. (2021) developed an anomaly detection system where self-attention was used to detect harmful actions from industrial control systems, resulting in better accuracy and interpretability than RNNs and CNNs. Similarly, Tran et al. (2022) used a Transformer encoder model to detect live DDoS attacks in Software-Defined Networks (SDNs) with very low latency and high accuracy.

The most important advantage of the TMs is that they can capture short-term and long-term dependencies in the data with no limitation for sequence as in the case of RNNs. Moreover, the attention weights generated by the model can provide understanding of which features or events significantly impact the detection process, enhancing model interpretability—an important attribute in security applications.

Comparative Examination of DL Architectures

Several research studies have tried to compare various DL architectures for IDS. Shone et al. (2018) evaluated autoencoders, CNNs, and deep belief networks (DBNs), finding that CNNs provided the optimal balance between accuracy and efficiency for static feature sets. In the meantime, Diro and Chilamkurti (2018) evaluated CNN and RNN models for live attack detection, concluding that although RNNs excelled in sequential comprehension, CNNs were more appropriate for resource-limited settings.

Recent evaluations of Transformers indicate they could exceed CNN and RNN Models in detection precision and generalization ability. Nonetheless, the relative newness of Transformer implementations in IDS indicates that comprehensive benchmarks and standardized assessments are still required. Additionally, performance can differ significantly based on dataset properties, preprocessing methods, and model settings.

Train and Test Data Collections

The effectiveness and variety of datasets are vital in creating and assessing IDS Models. The NSL-KDD dataset is commonly used but has been criticized for being outdated and not representative of contemporary attacks. Recent datasets like CIC-IDS2017 and UNSW-NB15 offer more authentic traffic patterns and a wider variety of attack types. CIC-IDS2017 features realistic traffic situations such as brute-force attacks, DDoS, web threats, and botnets, making it a favored option for assessing contemporary IDS solutions.

In spite of their enhancements, these datasets continue to have drawbacks, including uneven class distribution, restricted labeling precision, and absence of adversarial instances. Tackling these problems is essential for developing strong and adaptable Models.

Overview of Deficiencies and Prospective Paths

Despite significant advancements in IDS capabilities due to deep learning, many challenges remain. This encompasses the requirement for more equitable and varied datasets, immediate optimization of Models, resilience against hostile dangers, along with enhanced integration with existing security structures. Additionally, the interpretability and transparency of DL Models continue to be issues, particularly in high-stakes situations where understanding is crucial for incident management and regulatory adherence.

There is an swelling interest in merging various DL architectures into hybrid Models, utilizing the advantages of each. For example, CNN-LSTM or Transformer-CNN architectures might provide a deeper insight into both spatial and temporal dimensions of network data. Moreover, utilizing transfer learning and continual learning techniques could enable IDS to adjust to emerging threats without needing to retrain entirely.

III. METHODOLOGY

Research Framework

This research employs an experimental design to assess and contrast the efficacy of three deep learning frameworks—CNN, RNN, and TMs—for detecting intrusions in real time. The main objective is to gauge the accuracy, generalization ability, and inference speed of each model on contemporary cybersecurity datasets that replicate real-world network traffic.

Choosing and Preparing the Dataset

For this research, two commonly recognized benchmark datasets were chosen: CIC-IDS2017 and UNSW-NB15. These datasets cover various attack types, such as DDoS, brute-force, botnets, port scanning, and data exfiltration, rendering them appropriate for assessing the effectiveness of IDSs.

The preprocessing stage consisted of:

1. **Data Cleaning:** Eliminating absent values and unhelpful features.
2. **Normalization:** Adjusting numerical features through Min-Max normalization to maintain uniform input ranges.
3. **Encoding:** Transforming categorical variables into numerical format through one-hot encoding.
4. **Shuffling & Splitting:** Segmenting the dataset into training (70%), validation (15%), and testing (15%) portions.

Model Architectures

Convolutional Neural Network (CNN)

The CNN model incorporated several convolutional layers, succeeded by max-pooling and dropout layers to capture spatial patterns inside the data. The last layers featured a flatten operation and fully connected dense layers, concluding with a softmax activation function for classifying multiple categories.

Recurrent Neural Network (RNR)

The RNN structure utilized LSTM layers to capture temporal relationships in sequential network traffic information. The architecture consisted of two LSTM layers stacked with dropout for regularization, succeeded by dense output layers.

Transformer Architecture

The TM utilized an encoder-only structure featuring multi-head self-attention mechanisms and positional encoding to grasp both short- and long-range dependencies Layer normalization and dropout were applied consistently to prevent overfitting and speed up convergence

Training Specifications

Every model was trained utilizing:

1. Optimizer: Adam

2. Loss Function: Categorical Cross-Entropy
3. Size of Batch: 64
4. Epochs: 50 (utilizing early stopping determined by validation loss)
5. Learning Rate: Set initially at 0.001 with a decay plan

Training was conducted with TensorFlow on a GPU-equipped system to enhance computations and replicate live performance.

Assessment Metrics

To gauge each Models effectiveness, the following metrics were employed:

1. **Precision:** General correctness of classification.
2. **Precision, Recall, and F1-Score:** To assess performance for each class, particularly in situations of class imbalance.
3. **False Positive Rate (FPR):** To assess the rate of benign activities mistakenly identified as suspicious.
4. **Inference Duration:** Time required for each sample to gauge the practicality of live detection.
5. **Area Under the Receiver Operating Characteristic Curve (AUC):** Evaluates overall detection performance at different thresholds.

Real-Time Simulation

To replicate actual deployment scenarios, a live detection simulation was performed in which preprocessed traffic flows were transmitted in batches through every Model Latency was assessed from data entry to classification output to evaluate compatibility for live settings.

Comparative Analysis Method

A direct comparison of CNN, RNN, and TMs was conducted utilizing the same datasets and training methods. The final outcomes were compiled and examined to emphasize:

1. Detection effectiveness across attack types.
2. Speed versus accuracy trade-offs.
3. Generalization to previously unseen attacks.

IV. RESULTS AND DISCUSSION

Summary of Model Effectiveness

The effectiveness of the three deep learning Models—CNN, RNN (LSTM variant), and Transformer—was assessed using various metrics like accuracy, precision, recall, F1-score, false positive rate (FPR), and inference duration. All Models were trained and evaluated on the CIC-IDS2017 and UNSW-NB15 datasets utilizing the identical preprocessing pipeline and hardware configuration to guarantee an equitable comparison. The study examined both the effectiveness of detection and live practicality, since IDSs need to be not only precise but also function within time limitations in real-world settings.

Precision and Identification Efficacy

Accuracy is an essential overall measure of correct model decision; however, depending on imbalanced cybersecurity datasets, metrics like precision and recall become relevant. The results indicated that the Transformer outperformed the CNN and the RNN in overall accuracy, achieving 98.4% on CIC-IDS2017 and 96.8% on UNSW-NB15. CNN scored 96.3% and 94.7%, while RNN (LSTM) had 95.2% and 92.9%.

Each attack category's precision and recall were determined. CNN Models kept strong accuracy in identifying brute-force and DoS attacks, even though some slight recall degradation crept in for the more discreet threats like infiltration and web attacks. The RNN Model showed great recall for the time-sensitive attacks like botnets and port scanning but was troubled in terms of precision probably due to its propensity to overfit on some sequences. The Transformer, meanwhile, maintained both high precision and recall for nearly all attack categories, exhibiting credible generalization over multiple threat patterns.

F1 Score and False Positive Rate

The F1-score, representing the harmonic mean of precision and recall, emphasized the equilibrium between identification and misclassification. In the CIC-IDS2017 dataset, the TM achieved an exceptional average F1 score of 0.974, CNN scored 0.948, and RNN was trailing at 0.936. Again, the UNSW-NB15 dataset saw the Transformer sitting atop the throne with a score of 0.961, with CNN at 0.933 and RNN at 0.918. These scores prove the Transformer to be one precise

and reliable model across differing attack types and regular traffic.

Now, a metric to lower false alert reports upon the security team of paramount significance is the false positive rate. Here again, the Transformer manages amazingly well compared to others, recording an FPR of 1.2% on CIC-IDS2017 and 2.1% on UNSW-NB15. In comparison, CNN has its FPR marginally higher at around 2.7% and 3.3%, whereas RNN holds the highest FPR, even surpassing 4% at times depending upon the attack category. In other words, the slightest reduction in FPR gains ample amounts in operational cost reduction and alleviating alert fatigue in the actual scenario.

Inference Duration and Real-Time Viability

Inference time was computed as an average duration of every model in classifying one sample during the live simulation. This metric is critical in judging if a Model is suited for ad-hoc network scenarios. CNN attained the quickest inference time with an average of 2.3 ms per sample due to the feedforward nature of this network along with good GPU utilization. The Transformer, with an average time of 3.6 ms per sample, though slightly slower than CNN, is still comfortably within acceptable bounds for live use. RNNs were slowest with an average time of 6.8 ms per sample. The contiguous nature of RNNs adds to this delay, rendering them free-for-all in scenarios requiring prompt threat reaction.

Examination of Detection by Kind of Attack

An in-depth examination was carried out to comprehend the strengths of each Model concerning particular types of attacks:

1. **DoS/DDoS Attacks**: The three Models all exhibited strong performance, with Transformers attaining almost flawless detection because of their ability to capture increases in traffic volume and contextual trends.

2. **Brute-Force and Infiltration:** The CNN outperformed the RNN marginally, while the TMs exhibited the most consistent detection, presumably due to attention mechanisms that identify nuanced changes in authentication patterns.

3. **Botnets and Port Scanning:** RNNs benefited from their ability to model time, but Transformers outperformed RNNs in accuracy and recall, demonstrating their capacity to identify long- and short-term dependencies without sequential limitations.

4. **Web Attacks and Data Exfiltration:** Transformers were more proficient at detecting these intricate, often low-volume attacks because of their awareness of global context. CNNs exhibited the poorest results in this category, probably owing to their emphasis on local patterns.

Extension to Unknown Dangers

Zero-day or previously-unknown threats are the mainstay of many modern-day IDSs. To evaluate this generalization effect, the Models were tested on a portion of traffic data where known attacks manifested in new forms, alongside synthetic patterns not presented to the model during training. The Transformer, clearly, generalized far better to these new attacks, attaining an accuracy of more than 90% in unseen threat detection, with CNN and RNN reaching 82% and 76%, respectively. This emphasizes that attention-driven architectures are of great importance for IDSs, concerning flexibility and robustness.

Limitations and Practical Considerations

While deep learning methods are often considered as black-box Models and subject to criticism, attempts at their interpretation have shown promise recently. By looking at attention visualization in TMs, researchers could identify the parts of the input that influenced the detection decision the most. This can help analysts understand why an alert was triggered and aid in forensic investigations. CNNs can be interpreted somewhat through filter visualization; however, RNNs still tend to be rather obscure. The higher clarity of Transformers gives them real-world utility in security operation centers (SOCs), where understanding is paramount for decision-making.

Constraints and Practical Considerations

Even with the good performance of deep learning Models, much remains to be done. The dataset bias may be an important challenge-whilst CIC-IDS2017 and UNSW-NB15 are relatively large, one may argue they simply cannot replicate the conditions of real traffic over different sectors. These allow for a highly computationally intense training process, especially as Transformers demand special hardware with large amounts of time for the Model to converge. Drift in

the model may also happen with time as attackers will change their strategies to evade detection, thereby keeping constant retraining or an online learning system to keep on effectiveness.

Another major problem is that adversarial attacks can occur. Recent literature suggests that deep learning Models are susceptible to adversarial inputs—traffic patterns that have been altered slightly to throw off the Model from proper classification. This paper does not focus on this aspect; however, future implementations should consider testing defenses to sustain adversarial interference.

Overview of Comparative Results

Considering the experiments and metrics evaluated, the TM distinctly offers the best possible balanced performance, featuring high precision, very low false positive rate, good generalization capacity, and reasonable inference speed; thus, it is the foremost candidate for live intrusion detection in modern network settings. CNNs would still be preferable in environments where speed matters and resource availability is limited, while RNNs fall behind with their high rate of false positives and slow processing time, even though they are good at sequence Modeling.

V. CONCLUSION AND FUTURE WORK

The growing complexity and volume of cyber threats in contemporary digital frameworks have underscored the immediate demand for intelligent, adaptable, and live IDSs. This study examined the use and relative effectiveness of three deep learning Models—CNN, RNN, and Transformer architectures—for live threat detection in cybersecurity. All Mods were evaluated on CIC-IDS2017 and UNSW-NB15 using accuracy, precision, recall, F1, FP, inference time, and generalization. Results show Transformer-based model offers the best balance of precision, live inference, and robustness across attack classes. CNN model excels at attacks with uniform, repetitive patterns, aided by fast computation and spatial FE, making it ideal for low-latency use, though weak in capturing long-term dependencies or subtle threats.

LSTM-RNN performs moderately well in timed attacks such as botnet or scans. But due to high computational requirements and substantially low inference speed, the system just cannot fit in either a large-scale or resource-tight environment for live application CNNs and RNNs face limitations, with RNNs prone to false positives and poor generalization to new attack variants. In contrast, Transformer outperforms across most metrics, leveraging attention to capture both local and global data relationships, enabling faster training/inference and stronger zero-day generalization.

Attention-weight analysis also boosts interpretability for forensic and operational clarity. With its ability to manage large data volumes with minimal preprocessing, Transformer is well-suited for modern network security frameworks. Despite benefits, DL-based IDS face challenges: the need for robust datasets against evolving threats, defenses against adversarial interference, and minimizing false positives to sustain efficiency. Nonetheless, Transformer-based Models remain the most recommended for future cyberspace security systems.

Future Work

Based on the findings of the study, multiple such avenues are proposed to investigate existing challenges and increase the efficiency of DL in live IDS.

To boost the generalizability of the Models, it would be essential to include more diversified and dynamic datasets. Whilst considered respectable, both CIC-IDS2017 and UNSW-NB15 perhaps did not fully cover the changing nature of real-world traffic, especially with the fast-paced rise of IoT devices, cloud-native apps, and encrypted communication. Future research must ponder creating Models that are robustly calibrated for various domains and conditions by considering bigger data sets involving traffic from different environments and emerging attack types.

The second concern for an AI-grounded security system is adversarial attacks. They are the weakness of a system model because adversaries can fabricate inputs that appear harmless but are meant to evade detection by the Models. Future research needs to address adversarial training methods and input cleaning and apply generative Models in imitating adversarial actions. Defensive methods such as adversarial dropout, robust optimization, and defensive distillation should be evaluated in IDS

scenarios to harden deep learning models against these threats.

Third, **the interpretability and transparency of Models** are essential for real-world implementation, especially in regulated industries such as finance, healthcare, and critical infrastructure. Although TMs provide a degree of interpretability via attention maps, there exists a need for more user-friendly and comprehensible frameworks. XAI methods such as SHAP or LIME can assist in converting elaborate model decisions into an insight that people can comprehend, thus improving security analysts' trust and responsiveness to system alerts.

An important research area should be **online learning and incremental learning**. Offline or static Models developed with historical data will become outdated as new threats develop. If Models are designed to continuously learn from streaming data from the network without being completely retrained, adaptability and operational efficiency will be enhanced. How can continual learning, transfer learning, and reinforcement learning be exploited for allowing Models evolve gradually while retaining knowledge they have already learned?.

A very interesting problem for optimization arises, as an edge topology learns optimization applications in the geographical distribution over the network. Since recently networks are deployed over edge devices such as routers, gateways, and IoT nodes, they are becoming progressively necessary to carry out intrusion detection at the edge for time-to-response and threat attribution. This, by all means, calls for lightweight Models with minimum memory consumption and high accuracy. Model pruning, quantization, and knowledge distillation could also be considered for reducing the model size while maintaining the detection accuracy.

Essentially, the focus must be on wider security ecosystem integration. Deep-learning-grounded IDS would be well served by integration into a wider security agenda involving firewalls, SIEM, threat intelligence sources, and analyst input. Further research can ponder upon how these elements can be oriented around the AI concept, leading to automatically intelligent SOCs that consist of automatic threat evaluation, meta-search ranking, and meta-response coordination.

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Adversarial Robustness in AI-Driven Cybersecurity Solutions: Thwarting Evasion Assaults in Real-Time Detection Systems

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Abstract *— The incorporation of Artificial Intelligence (AI), especially deep learning models, into cybersecurity frameworks has greatly improved the identification and mitigation of cyber threats. Nonetheless, these smart systems encounter a significant and rising threat – adversarial attacks. Malicious entities create subtle alterations in network traffic or system actions that mislead AI models into misidentifying threats as harmless, facilitating evasion tactics that can circumvent real-time intrusion detection systems (IDS). This study investigates the susceptibility of deep learning-based Intrusion Detection Systems (IDS) to adversarial examples and suggests a robust detection framework aimed at improving resilience against these evasion tactics. The suggested system merges adversarial training, input sanitization, and resilient model architectures, including adversarial-aware Convolutional Neural Networks (CNN) and defensive autoencoders. Employing benchmark datasets like CIC-IDS2017 and UNSW-NB15, we recreate various adversarial scenarios – created using Fast Gradient Sign Method (FGSM) and Projected Gradient Descent (PGD) – to evaluate the effect on detection performance. Experimental findings indicate that conventional DL models experience a significant decline in performance when exposed to adversarial circumstances, with accuracy decreasing by more than 20% in certain instances. Conversely, our suggested framework shows a noticeable enhancement in adversarial robustness, keeping more than 91% detection accuracy during attacks and considerably lowering false positives.*

Keywords *— **Cybersecurity, Intrusion Detection, Deep Learning, RNN, Transformer***

I. INTRODUCTION

The rapid advancement and integration of Artificial Intelligence (AI) and deep learning models into cybersecurity frameworks have ushered in a new era of intelligent threat detection and mitigation. Artificial intelligence systems that use deep neural networks are very good at finding complicated patterns in user behavior and network traffic. This lets you quickly find bad actions before they are found by traditional signature-based or heuristic detection. As they take on more important roles in the cybersecurity business, they have also shown that they can be vulnerable to attacks by bad actors. Evasion attacks are a kind of adversarial assault that change inputs so that AI models think that poor behavior is good. When AI-based cybersecurity solutions are used in the real world, this flaw makes them less reliable, strong, and safe.

Adversarial machine learning looks at how bad people can change machine learning systems.

A lot of people have been interested in this area of study in the last several years. Circumvention attacks

are a special kind of danger in cybersecurity because they change the judgment boundaries of detection algorithms by making tiny changes to the input data.

These changes usually go unnoticed by human analysts, but they are enough to cause misclassification. Attacks like these can do a lot of harm to intrusion detection systems (IDS), which lets attackers get access networks, steal data, or disrupt services without setting off alerts. This is a big problem in real-time detection settings where immediate action is needed to stop more damage. Cybersecurity data is quite complicated, and cyber threats are getting worse very quickly, which makes it even harder for enemies to avoid detection.

System logs and network traffic are various from one another in significant and complex manners. It's very difficult to construct detection models that are robust. Also, the fact that methods of attack are constantly improving and becoming more complex, like polymorphic malware and advanced persistent threats, makes the models more robust and resilient.

Adversarial attacks exploit vulnerabilities by introducing harmful patterns into what appear to be normal communications or user actions, which is difficult for traditional detection software to discover. Deep learning frameworks, such as Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), and, more recently, Transformer-based networks, have been instrumental in most AI-based Intrusion Detection Systems (IDS) since they are capable of learning hierarchical and temporal features directly from raw or lightly preprocessed data.

These models make use of statistical trends and decision boundaries learned from training data, which make them vulnerable to subtle yet carefully constructed input changes. Attackers can employ gradient-based approaches such as the Fast Gradient Sign Method (FGSM) or Projected Gradient Descent (PGD) in order to craft samples that manage to bypass defenses. The vulnerabilities of these attacks indicate that AI-powered cybersecurity algorithms are just as vulnerable; while such models enhance the detection of threats, their built-in susceptibility to evasion techniques undermines their reliability and effectiveness.

Thus, one of the main research areas in AI-based cybersecurity is making it more difficult for adversaries to continue. More specifically, designing detection techniques that are able to discover known threats as well as threats that have been altered on intent, as well as ensuring that they remain resilient during an attack and are discovered quickly and precisely.

There are a variety of methods with which to resist hostile attacks.

Adversarial training entails training models with adversarial examples so that they become stronger. Input sanitization and transformation strategies attempt to eliminate adversarial noise prior to classification, and architectural enhancements attempt to render models more resilient to input change. Every approach has its downsides, which may translate to increased processing expense, reduced model flexibility, or reduced resilience to novel hostile tactics.

It is exceedingly hard to keep real-time detection working while also putting in place defenses against attackers. Cybersecurity technology must work within strict latency limits so that problems may be found and fixed right away.

Some adversarial defense tactics make things harder or require more work, which makes them hard to use in real-time networks where efficiency and scalability are very important. Because of this, there is a big need for robust but light models made just for cybersecurity that can handle attacks. AI-powered Intrusion Detection Systems must not only be effective but also intelligible and transparent. Security experts need to know why they give warnings in certain scenarios, especially when false positives can lead to expensive investigations and problems with operations. Adversarial attacks make this even more important by hiding the reasons for their scary effects. Combining explainable AI (XAI) techniques with adversarial robustness tactics may make model outputs clearer, build trust, and make it easier to do forensic analysis during incident management.

The research community is actively focusing on the unification of several defense techniques into comprehensive frameworks that together bolster enemy resilience. Hybrid approaches that combine adversarial training with input preprocessing and architectural enhancements have demonstrated potential in achieving a balance between detection

effectiveness and resilience. Adaptive protection mechanisms that use reinforcement learning and continuous learning let AI systems change their defenses when new attack methods are used. This is similar to the "arms race" that happens in cybersecurity.

This study focuses on developing and evaluating a comprehensive detection framework that is robust against adversarial assaults for real-time cybersecurity applications. Utilizing benchmark datasets like CIC-IDS2017 and UNSW-NB15, the system combines adversarial-aware convolutional neural networks with defensive autoencoders and strong input sanitization processes. The assessment replicates diverse evasion attack situations employing advanced adversarial example creation methods, methodically evaluating model performance decline and resilience enhancements. By means of thorough experimentation, this study seeks to deliver practical insights into efficient defenses against evasion attacks and create actionable recommendations for implementing secure AI-based IDS.

The rest of the paper is structured as follows: subsequent to this introduction, we examine pertinent studies in adversarial machine learning and cybersecurity; then, we outline the methodology encompassing dataset preparation, adversarial attack simulation, and model architecture; thereafter, experimental findings are presented and discussed; ultimately, conclusions are made along with a roadmap for future research avenues. This study enhances the field by connecting theoretical adversarial robustness with practical cybersecurity requirements, highlighting the essential importance of robust AI models in protecting digital infrastructures from advancing cyber threats.

II. LITERATURE REVIEW

Overview of Adversarial Machine Learning in Cybersecurity

Adversarial machine learning is a developing area that examines the weaknesses of AI and machine learning systems to intentionally designed inputs aimed at misleading the model. Adversarial assaults are a big threat to cybersecurity, especially when AI-powered intrusion detection systems (IDS) are used. I Adversarial attacks are different from conventional threats since they directly attack AI models by making alterations that cause them to misclassify or evade. People may not notice these little changes, but they are enough to trick the model into generating false predictions, which can lead to security issues.

Evasion attacks are the most common sort of threat in the realm of cyber security. Attackers modify bad traffic or payloads so that AI-based IDS can't see them. It's tougher to carry out these attacks now that it's easier to build adversarial instances, thanks to tools like the Fast Gradient Sign Method (FGSM) and Projected Gradient Descent (PGD). These strategies exploit the model's loss function's gradients to provide inputs that make the model's prediction error worse while still achieving its goal of destruction. You need to know these strategies and how they function in order to build good defense plans.

AI-Driven Intrusion Detection Systems and Their Weaknesses

AI and deep learning have altered how intrusion detection works by allowing systems find complicated patterns in huge datasets without having rules that people made. Some models that are highly good at finding sophisticated and zero-day attacks are Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), and Transformer architectures. But because these models depend on statistical learning, they are open to hostile inputs that take advantage of established decision boundaries.

Numerous studies have demonstrated the ineffectiveness of AI-driven Intrusion Detection Systems (IDS) against adversarial evasion. For example, Grosse et al. (2017) showed that adversarial samples made for deep neural networks might successfully get past malware classifiers. In a similar study, Huang et al. (2019) demonstrated that adversarial network traffic generated via gradient-based attacks might circumvent intrusion detection systems through deep learning. These results indicate that while AI enhances detection capabilities, it simultaneously generates new attack vectors that require attention.

Techniques for Adversarial Attacks in Cybersecurity

In cybersecurity, adversarial attacks mainly focus on feature representations derived from network traffic or system logs. Frequent tactics used in attacks consist of:

1. **Fast Gradient Sign Method (FGSM**): Developed by Goodfellow and his team. (2015), FGSM generates adversarial examples by adding disturbances according to the gradient's sign of the loss function. It is computationally efficient, but produces rather simple adversarial examples
2. **Projected Gradient Descent (PGD):** As an iterative enhancement of FGSM, PGD executes several steps of minor disturbances, followed by a projection back into the legitimate input space. It is considered a more potent assault and a typical standard for adversarial resilience.
3. **Carlini & Wagner (C&W) Attacks:** These methods refine perturbations using a loss function crafted to reduce detection confidence, yielding potent yet computationally intensive adversarial instances.

These methods emphasize how easily attackers can create inputs that bypass AI detection when no protective measures exist.

Defensive Approaches to Counter Adversarial Attacks

To address adversarial threats, researchers have suggested multiple defense strategies focused on enhancing model resilience:

Adversarial Learning

Adversarial training is adding adversarial samples to the training dataset to help the model learn how to recognize and fight them. Goodfellow et al. (2015) started this technology, which has been very successful in image recognition tasks and is slowly being adapted for use in cybersecurity. Adversarial training requires substantial computational resources and may not be effective against all types of adversarial attacks, especially novel ones.

Input Alteration and Cleaning

Preprocessing techniques aim to remove or reduce adversarial changes from inputs before the detection model processes them. To make hostile inputs less effective, people have recommended using techniques like feature squeezing, input noise reduction, and randomization. Xu et al. (2017) introduced feature squeezing, a method that reduces input precision to limit adversarial noise, demonstrating improved resilience in malware detection. However, if these methods are used too strongly, they could make the model less effective on clean data.

Sturdy Model Designs

Certain work concentrates on modifying the architecture to enhance the built-in robustness of the model. Defensive autoencoders, which are designed to reconstruct inputs to eliminate noise, have been employed to eliminate adversarial perturbations. Other researchers have explored models that integrate convolutional layers with recurrent or attention mechanisms to acquire feature representations that are richer and less susceptible to adversarial attacks. The objective of such designs is to achieve a balance between efficiency in computing and strength that is appropriate for real-time systems.

Identifying Adversarial Examples

Another method to protect against attack is to train various models to identify if an input is malicious. These detectors search for unusual patterns in input space typical of adversarial noise. Detection models are promising but struggle to maintain low false positive rates and adapt to novel methods employed by attackers.

Difficulties in Real-Time Adversarial Protection

There are several issues with introducing adversarial resilience into real-time IDS. Security can slow the process of determining and correcting problems, making the system less practical. Furthermore, it is imperative to maintain low false positive rates operationally to prevent security analysts from becoming desensitized to alarms. It is imperative to use caution in balancing strength, precision, and quickness.

The nature of the attacks is ever evolving. The assailants consistently refine their tactics, necessitating that detecting systems perpetually enhance their defenses. Without online learning or adaptive approaches, static models quickly become useless. This illustrates the importance of systems that encourage ongoing improvement.

Upcoming Trends and Future Paths

Recent advancements suggest the potential for integrating several defense systems to leverage their synergistic benefits. Combining adversarial training with input filtering and tougher designs could give

you many degrees of protection. Reinforcement learning techniques have been proposed to enable models to dynamically adjust defenses in response to attack attempt inputs. Explainable AI (XAI) is becoming more popular in this field since it lets you look at model decisions and see how bad changes affect them. When problems come up, clear models can keep people's attention, make them more comfortable, and help with investigations. Researchers are now looking into how well Attention-based Transformer models can stand up to cyberattacks. These models are known for their ability to generalize and represent features better than other types of models.

Their capacity to simulate long-range dependency can help find complicated and subtle threat indicators.

III. METHODOLOGY

This study introduces a thorough experimental methodology for evaluating and enhancing the adversarial resilience of deep learning-based intrusion detection systems (IDS).

The procedure encompasses dataset preparation, generation of adversarial assaults, model construction, implementation of adversarial defense, establishment of training configurations, and evaluation of model performance. The primary objective is to determine how various security techniques improve AI-based models in detecting evasion attacks within real cyber-protection contexts.

Research Design

The study employs a comparative and experimental framework in which various deep learning models are trained on both clean and adversarial modified data to evaluate their detection performance. The framework consists of three stages: training a baseline model lacking adversarial protections, simulating and assessing adversarial attacks, and applying defense strategies to improve model resilience. The assessment depends on the performance of classification in both standard and hostile settings

Data set Choice and Preparation

Two benchmark datasets were chosen for testing:

1. **CIC-IDS2017**: An extensive dataset offered by the Canadian Institute for Cybersecurity. It comprises both harmless and harmful network traffic reflecting modern attack patterns such as DDoS, brute-force, infiltration, botnet, and web-based attacks. The dataset emulates authentic user activity and network systems.
2. **UNSW-NB15**: Developed by the Australian Centre for Cyber Security, this dataset features nine distinct attack types in addition to regular traffic. It records actual contemporary network traffic along with application layer and payload details.

Preprocessing consisted of multiple essential stages

1. **Selection and Cleaning of Features:** Features that had constant values or missing data were eliminated. Unrelated attributes such as timestamps or non-numeric identifiers were removed.
2. **Normalization:** Applying min-max normalization for feature scaling to maintain uniform input ranges.
3. **Categorical Encoding:** One-hot encoding was utilized to transform categorical variables into numerical representations.
4. **Data Balancing:** The issue of class imbalance was tackled through the use of the Synthetic Minority Oversampling Technique (SMOTE) to improve model generalization and lessen bias towards the majority classes.
5. **Train-Test Split:** Train-The dataset was separated into training (70%), validation (15%), and testing (15%) sets.

Adversarial Attack Generation

To assess the susceptibility of detection models, adversarial examples were generated utilizing two well-known methods:

Fast Gradient Sign Method (FGSM)

FGSM generates adversarial examples by introducing noise to the input following the gradient of the loss function concerning the input. It is calculated as:

$$x\_adv = x + \varepsilon * sign(\nabla_x J(\theta, x, y))$$

Where:

1. **x_adv** represents the adversarial input.
2. **x** represents the initial input.
3. ε represents the magnitude of the disruption

4. J (θ, x, y) denotes the loss function characterized by the parameters θ.

5. $\nabla_x J$ denotes the gradient of the loss with respect to x

6. FGSM is quick and efficient, which makes it ideal for replicating fundamental adversarial scenarios**.**

Projected Gradient Descent (PGD)

PGD is a more robust, iterative method that uses FGSM in incremental steps and maps the altered input back into the ε-ball surrounding the original input. It is broadly regarded as a reliable assessment for adversarial strength.

Adversarial examples were produced for both datasets, forming situations where harmful traffic is minimally modified yet maintains its damaging traits, mimicking actual evasion attacks.

Architecture of the Model

The primary deep learning model employed for assessment is a combined adversarial-aware structure integrating CNN and autoencoders.

Convolutional Layers: Retrieve spatial characteristics and local patterns from network traffic streams.

Autoencoder Block: Created for reconstructing inputs to eliminate adversarial noise, enhancing the model's resilience to minor disturbances.

Dense Layers: Conduct the final classification into attack or benign categories utilizing softmax activation.

We trained a simple CNN model with no protections simultaneously with the proposed hybrid model to gauge how potent it was. This provided a baseline for how performance should decrease when things fail.

Mechanisms for Defending Against Adversaries

Multiple defense strategies were incorporated into the model pipeline:

Adversarial Training

We used both clean and hostile samples to teach the models again. This strategy helps the model find patterns that are trying to trick it and move decision boundaries so that changes are less likely to effect it.

Input Validation

As a precursor to transmitting information to the classifier, a denoising autoencoder receives a compressed clean input. This assists to eliminate small issues that get in the way and recover critical data features.

Feature Squeezing

The accuracy of feature values was decreased to diminish the impact of gradient-based attacks. Feature squeezing serves as a preliminary filter, diminishing input dimensionality and the area of adversarial surfaces.

Defensive Dropout

Dropout layers were implemented to improve model generalization and lessen overfitting. This also introduces stochastic behavior, complicating attackers' ability to anticipate model output based on static gradients.

Training and Parameter Tuning

Every model was trained following this configuration:

1. **Optimizer:** Adam
2. **Objective Function:** Categorical Cross-Entropy
3. **Size of Batch**: 64
4. **Epochs:** 50 with early termination
5. **Learning Rate:** 0.001 with reduction

The models were developed using TensorFlow and trained on a GPU-accelerated system to enhance convergence speed and facilitate experimentation. Hyperparameters were adjusted through grid search and cross-validation on the validation set to enhance performance in both adversarial and clean situations.

Assessment Criteria

To evaluate both standard and adversarial performance, the subsequent metrics were utilized:

1. **Accuracy:** Proportion of correctly classified samples.
2. **Recall:** Proportion of true positives among actual positives.
3. **F1-Score:** Harmonic mean of precision and recall.
4. **False Positive Rate (FPR):** Proportion of harmless inputs incorrectly identified as threats.
5. **Adversarial Accuracy:** Model effectiveness on adversarial examples.
6. **Inference Duration:** Average time taken to process a sample, to assess real-time applicability.

Environment for Real-Time Simulation

To replicate deployment in an active network, a streaming setup was established where traffic samples were consistently provided to the model. Inference latency was evaluated for each sample to confirm that the defense mechanisms did not significantly prolong detection. A maximum allowable latency limit of 5 milliseconds per sample was applied to assess real-time viability.

IV. RESULTS AND DISCUSSION

This segment outlines the empirical results from our experiments focused on assessing and enhancing adversarial resilience in AI-driven cybersecurity systems. The findings are analyzed regarding conventional detection performance, the influence of adversarial assaults, and the efficacy of different defense measures within real-time limitations. All experiments were carried out utilizing the CIC-IDS2017 and UNSW-NB15 datasets, as outlined in the preceding section.

Baseline Achievement on Untainted Data

The baseline performance of the initial models—standard CNN (baseline) and hybrid CNN-Autoencoder—was determined by training and testing them on clean, unaltered data. The CNN model achieved an accuracy of 97.1% on CIC-IDS2017 and 95.3% on UNSW-NB15, with both precision and recall exceeding 94%. The hybrid model marginally exceeded the baseline, reaching accuracies of 98.2% and 96.7% on the corresponding datasets. The F1-scores were 0.975 and 0.961, demonstrating a remarkable equilibrium between precision and recall. These findings validate that deep learning models are very efficient at detecting recognized and varied cyber threats in clean environments.

Performance in the Face of Adversarial Assaults

To assess adversarial weakness, both models were subjected to inputs altered through FGSM and PGD attacks. The outcomes were striking. With FGSM ε = 0.02, accuracy of the baseline CNN on CIC-IDS2017 dropped from 97.1% to 76.4%, and for PGD (with 10 iterations), the drop was even larger, to 69.3%. Similar trends were observed on UNSW-NB15 with the drop from 95.3% to 73.5% (FGSM) and 66.1% (PGD). This drop shows how susceptible the models are to minor variations in inputs and that it is imperative to include adversarial defense in actual IDS.

The hybrid model showed enhanced robustness but nevertheless had a marked decline in performance Accuracy fell to 84.7% for CIC-IDS2017 and 81.3% for UNSW-NB15 due to FGSM attacks. For PGD, accuracy fell to 77.2% and 74.9%, respectively. As much as these figures depict increased strength over the baseline, the results show that even advanced models are not provided with sufficient protection from deliberate adversarial attacks without proper defensive measures.

Efficacy of Adversarial Training

Adversarial training greatly enhanced the model's robustness. When re-trained with a combination of clean and adversarial examples (FGSM and PGD), the hybrid model showed significantly reduced performance declines when facing attacks. In CIC-IDS2017, the accuracy with FGSM perturbation increased to 91.4%, while PGD reached 88.9). These findings suggest that adversarial training enhances the model's decision boundaries and boosts generalization to adversarial inputs, though it results in a minor decline in performance on clean data (a decrease of about 1.2%).

Significantly, adversarial training also resulted in a decrease in the false positive rate (FPR). With clean data, the FPR of the adversarially trained model stayed below 2.1%, whereas the non-hardened version had 3.6%. This indicates that the extra resilience gained from adversarial training might also lower overfitting, enhancing the model's overall stability.

Effectiveness of Input Filtering (Autoencoders)

Incorporating a denoising autoencoder into the model pipeline to clean inputs prior to classification improved both accuracy and adversarial robustness. For adversarial inputs created through FGSM, the model with sanitization maintained 89.8% accuracy on CIC-IDS2017 and 86.1% on UNSW-NB15. In opposition to PGD, it preserved 84.2% and 80.3% correspondingly. Although somewhat less effective than adversarial training, this method is model-independent and can be implemented as a preprocessing filter for any IDS.

The integration of autoencoders with adversarial training produced the optimal outcomes, showcasing supplementary advantages. The hybrid model,

developed through adversarial methods and improved with input cleaning, achieved 93.5% accuracy on FGSM and 90.8% on PGD for CIC-IDS2017.onUNSW-NB15, results were 91.7% (FGSM) and 88.5% (PGD), indicating that integrating defenses yields a synergistic benefit.

Effects of Feature Squeezing

Feature squeezing, being a lightweight preprocessing method, minimally decreased model vulnerability. It enhanced adversarial accuracy by 4–6% in most instances but had a detrimental impact on clean data performance. Specifically, it resulted in a slight decline in the accuracy of clean data (around. 1.8%) because of its lossy characteristics. Although it isn't a complete solution, feature squeezing can be an effective part of a multilayered defense approach, especially in settings where computational limitations restrict the application of more complex models.

Performance of Real-Time Inference

A vital necessity for IDS is operation in real-time. We evaluated inference latency for all models to determine their feasibility for use in active network settings. The typical CNN model exhibited an average inference time of 2.3 milliseconds for each sample. The hybrid model (including autoencoder) raised latency to 4.7 milliseconds. Through adversarial training and sanitization, overall latency achieved 5.6 milliseconds—within the permissible limit for real-time detection (≤ 6 ms).

Even though extra defensive layers add computational costs, the compromise was warranted due to greatly enhanced adversarial resilience. Crucially, throughput stayed consistent at over 200 samples per second, confirming the practicality of implementing these models in operational settings where both speed and precision are essential.

Dialogue and Consequences

The results of this research strengthen the argument for going beyond accuracy as the only performance measure for AI-driven cybersecurity systems. The experiments show that models that excel on clean data can be greatly affected by adversarial disturbances. Therefore, adversarial robustness should be a fundamental factor in the design of IDS.

Additionally, a tiered defense strategy—combining adversarial training with input sanitization and a strong architecture—provides greater durability than any individual method by itself. Even though this introduces greater complexity, the advantages in security-sensitive applications significantly surpass the drawbacks. The minimal rise in inference time is controllable in the majority of practical scenarios, particularly considering the avoidance of expensive security violations.

These findings indicate a hopeful future path for AI in cybersecurity: systems that not only identify threats but also proactively adjust to changing attack methods. Incorporating explainability, ongoing learning, and reinforcement strategies can significantly boost trust, adaptability, and operational effectiveness when confronted with more advanced cyber threats.

V. CONCLUSION AND FUTURE WORK

The inclusion of artificial intelligence, especially deep learning, in cybersecurity systems has greatly improved real-time threat detection by automating the examination of intricate, large-scale network data. Nevertheless, this progress brings about new challenges. A primary concern is the susceptibility of AI models to adversarial attacks—particularly, evasion methods where precisely designed input alterations trick the model into incorrectly classifying harmful data as harmless. This research aimed to investigate the extent of this vulnerability and suggest a practical, effective, and robust framework that protects deep learning-based intrusion detection systems (IDS) from these evasion threats while maintaining real-time performance.

Intensive testing with the CIC-IDS2017 and UNSW-NB15 datasets shows that unprotected deep learning models, even those with high accuracy, are very vulnerable to adversarial disturbances. When adversarial training was applied using basic adversarial attacks, detection accuracy decreased by nearly 20–30% in certain instances. This indicates just how simple it is to attack these models.

Any performance decrease is unacceptable in cybersecurity because correct detection is required in both good and bad operating environments.

The study proposed a hybrid adversarial defensive mechanism employing various protective techniques, such as adversarial training, input purification via

denoising autoencoders, and convolutional filtering to enhance the architecture of the system. When combined, these methods made IDS models much less susceptible to deception by fictitious inputs. The top model, trained to be adversarial and employed a sanitization method, was able to identify over 90% of the attacks, including even the powerful ones such as PGD. The average inference delay of the model was slightly more than 5 milliseconds, which is important as it indicates it can detect intrusions in real time. What this implies is that you can have adversarial robustness without sacrificing speed or efficiency, a consideration for areas where security is crucial but a high amount of data must be processed quickly.

The model became more robust and contained less false positives. This means that defenses against adversaries would make the models more robust and ensure they perform better in new environments. These results imply that AI-based security systems are more secure and reliable when they employ design principles that take into account adversaries. Despite these achievements, the research indicated that there were still plenty of restrictions and opportunities for further development. Adversarial training made the model resilient to known attack techniques such as FGSM and PGD initially, but it was still defensive. It protects against certain types of noise in the training data, but it may not work so well against new or developing attack methods. This limit shows that we need to set up proactive security systems that can handle more forms of attacks than we have seen before. Second, the autoencoder-based cleaning process is effective, although it is slightly longer to execute. We discovered that our test environment had decent latency. Deploying into ultra-low latency environments, though, like in edge devices or mission-critical networks, might require more tuning or relaxed security restrictions.

It was easy and fast to learn the compressed properties, but they didn't have a significant impact and may not be sufficient to defend yourself independently.

Another problem is that attackers and defenders are engaged in a "arms race'' across the globe.

Defenses improve as do people's attacks. Adversarial methods such as GAN-based perturbations, black-box transfer attacks, and real-world executable tactics tend to predict the emergence of emerging ideas. Therefore, generating AI models with the ability to self-modify and adapt as well as continuously discover and react to new attack behaviors remains a high-priority goal for the future. Future research should center on the incorporation of explainable AI (XAI) methods into adversarially robust models. For operational assurance and post-attack analysis, particularly during an attack, it is crucial to understand the rationale behind a model's classification of an input as malicious or benign. In key situations where accuracy is equally as important as responsibility and openness, models that are easy to understand will be superior. Online education and continuous learning are other good ways to make models more flexible. Detection systems can change to keep up with new threats without needing to be retrained or putting security at risk. This lets models keep learning about new traffic patterns and ways that attackers can attack.

The study also facilitates the utilization of different modalities by opposing defenses. This study focused on network traffic data; however, the amalgamation of other data sources, including endpoint logs, system telemetry, and behavioral analytics, could provide a more thorough and resilient framework for threat identification. A model that integrates and cross-verifies information from many domains is inherently more resilient to deception, as it expands the adversarial assault surface required for successful evasion.

In conclusion, this research substantially contributes to the evolving field of adversarial cybersecurity by demonstrating that deep learning models, notwithstanding their vulnerabilities, can be enhanced by a judicious combination of protective techniques. The suggested adversarially robust framework offers theoretical understanding and practical approaches for improving the security of AI-driven intrusion detection systems. As cyber threats grow in complexity and nuance, creating resilient, adaptive, and explainable AI systems will be crucial for protecting digital infrastructure in real-time. The path to developing these systems is intricate and continuous, yet this effort signifies a crucial advancement toward that objective.

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Managing the Level of understanding in thesis writing among Grade 12 Students

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Abstract *— Thesis writing is an important part of senior high school education, especially under the K-12 curriculum. This study looked into how well Grade 12 students understand the different parts of thesis writing. It focused on four main areas: Chapter 1 (the problem and review of related literature), Chapter 2 (methodology), Chapter 3 (presentation, interpretation, and analysis of data), and Chapter 4 (summary, conclusion, and recommendation). The researcher used a descriptive survey method and gathered data from 725 Grade 12 students from selected public schools in Nueva Ecija. A survey questionnaire was used to measure students' level of understanding in each chapter. Results showed that students had a good level of understanding in all four chapters. In Chapter 1, they understood how to explain the importance of their study and relate it to existing literature. In Chapter 2, students could identify research methods and tools, but some needed more help with technical parts like sampling and statistics. In Chapter 3, they could present their findings clearly using visuals like tables and graphs, though some lacked depth in interpretation. In Chapter 4, they were able to write conclusions and recommendations based on their findings, but a few needed to improve clarity and completeness. This study suggests that while students have a generally good grasp of thesis writing, teachers still need to guide them more, especially in areas that are more technical or detailed.*

Keywords *— Methodology, Research Skills, Senior High School, Student Learning, Thesis Writing*

I. INTRODUCTION

Writing is a vital part of the research process. The activity of research involves writing, and research itself is a form of writing (Kamler & Thomson, 2014). Currently, under the new General Education Curriculum (K-12), students are exposed to various domains of knowledge, such as writing a thesis (Acosta, 2016).

According to Reynolds and Thompson (2017), writing a thesis in faculty-mentored undergraduate research is one of the best opportunities for students. But developing good writing skills cannot be achieved automatically. "There are significant challenges, issues and problems involved in the surface features of writing that focus on spelling, punctuation, grammar or simplified models of text structure or citation rules that supervisors, advisers, coaches or critics need to address to help students develop productive research or thesis writing practices" (Kamler & Thomson, 2014).

However, the most important factor in writing a thesis is the students' scientific and practical capabilities (Pfajfar, Mitręga & Shoham, 2024). "Lacking an appropriate level of understanding in thesis writing, such as in methodology and statistics, familiarity with scientific databases and their usage are the common problems encountered in writing a thesis" (Mizamy et al., 2012). So, in order to know the level of understanding of thesis writing among senior high school students, this study was conducted. Furthermore, this study aimed to answer the level of understanding in thesis writing (Subia et al, 2022) of the Grade 12 students in terms of problem and review

of related literature, methodology, results and discussion, summary, conclusions, and recommendations.

Prospectively, this study could help both educators and students. Educators will become aware of addressing the issue, while students will become more active and attentive to meet the high degree of understanding and capabilities with regard to thesis writing.

Finally, as the research president of the research society for teachers teaching research in the senior high school of DepEd Nueva Ecija, the researcher would easily identify known difficulties in writing research among students and teachers, this would open opportunity to intervene with the identified difficulties and would be able to come up with research output that would make research subject easier to teach and learn.

II. METHODOLOGY

In this study, the researcher chose a descriptive survey research design because it best served to answer the questions and the purposes of the study. A research design is basically a conceptual structure within which research is conducted. Parahoo (2013) described "the research design as a process that helps in planning the how, when and where of information collection and analysis". A survey questionnaire was used as the major instrument of this study. The questionnaire was a product of a pre–survey and at the same time a product of research after consulting various literature and studies related to the study itself.

Purposive sampling was used in this study. Parahoo (2013) describes purposive sampling as "a method of sampling where the researcher deliberately chooses who to include in the study based on their ability to provide necessary data. Grade-12 Senior High School Students under the Academic Track from the four big schools of DepEd Nueva Ecija were chosen purposively as respondents of this study (Subia, 2018). The set criteria for choosing the respondents were established to ensure accurate and reliable answers. A total of the target population 1929 (N) with 725 target sample (n). The results of the target sample were the total number of students in one section per academic strand. A total of seven hundred twenty-five (725) were served as the respondents of the study. It can be seen at the preceding table.

Table 1 Distribution of the Respondents

Schools	**Sections**				**Total**
	ABM	GAS	HUMSS	STEM	
Bongabon NHS	40	53	42	32	167
Cabiao NHS	43	52	54	36	185
Nueva Ecija NHS	50	49	49	43	191
Talavera NHS	48	50	50	34	182
Total					725

Appropriate statistical tools were used in this study. To assess the level of understanding of the respondents regarding research writing, the following scale was used:

Scale	**Mean Interpretation**
1.00-1.74	Poor
1.75-2.49	Low
2.50-3.24	Good
3.25-4.00	Excellent

For a better understanding of the verbal descriptions, these are interpreted as follows:

For the level of understanding of research writing:

Excellent. The understanding is highly extensive. The respondents have full knowledge of research writing.

Good. The understanding is extensive. There are items which the respondents are not aware of. Similarly, there are areas that the respondents do not give 100% attention to.

Low. The knowledge of the respondents is usual. There are items which they are aware of, while others are not known.

Poor. The respondents have little knowledge of the item.

III. RESULTS AND DISCUSSION

1. Level of Understanding in Research in terms of Problem and Review of Related Literature

Table 2 Level of Understanding in Writing Research The Problem and Review of Related Literature

		STUDENTS	
	ITEMS	**WM**	**Verbal Description**
	Chapter 1		
1	I know that I need to show that the conduct of the study is urgent.	2.88	Good
2	I know that I need to be aware of all the contents of my study.	2.81	Good
3	I know that research has a specific problem that needs to be identified.	2.78	Good
4	I know how to identify variables that are needed in my research problems.	2.69	Good
5	I know how to identify possible beneficiaries of my study.	2.69	Good
6	I know that I need to discuss the importance of my study.	2.77	Good
7	I know that I need to determine the area covered in my study.	2.70	Good
8	I know that I need to identify the duration/time of my study.	2.71	Good
9	I know that I need to discuss the purpose of my research study.	2.77	Good
10	I know that I need to identify specific accomplishments that my research is trying to achieve.	2.78	Good
11	I know that I need to be aware that I may define words conceptually or operationally.	2.70	Good
12	I know that I need to determine a theory that would support my study.	2.69	Good
13	I know that my study may contribute information material to a specific type of development.	2.73	Good
14	I know how to distinguish if the related literature and studies are also aligned in my study.	2.86	Good
15	I know that I need to avoid plagiarism.	2.78	Good
	Overall Weighted Mean	**2.76**	**Good**

Legend: 1.00-1.74 – Poor; 1.75-2.49 – Low; 2.50-3.24 – Good; 3.25-4.00 – Excellent

Table 2 presents the data gathered on the understanding of the grade 12 students in writing the research Chapter 1. From the table, it may be seen that the 15 items all obtained an average weighted mean of 2.76 and interpreted as "Good". Of the 15 items, *'' I know that I need to show that the conduct of the study is urgent"* obtained the highest weighted mean of 2.88.

This was followed by *"I know how to distinguish if the related literature and studies are also aligned in my study"* 2.86; *"I know that I need to be aware of all the contents of my study"* (2.81.

With the overall weighted mean of 2.76 from the responses of the students, it is clear that the respondents described their understanding of writing research, particularly on "The Problem and Review of Related Literature", to be extensive. There were items or parts of the research work that the respondents were not aware of. Similarly, there are areas that the respondents do not give 100% attention to.

To surpass challenges in research, a student–researcher must choose an effective research topic, develop a doable topic, determine the availability of time, money, and personnel, be knowledgeable and, more importantly, have an interest with regard to the chosen topic (Caintic & Cruz, 2011).

A full understanding of Chapter 1 is necessary since here; the research problem is located. It is the main organizing principle guiding the analysis of the topic. "It represents the core subject matter of scholarly communication, and the means by which it includes other topics of conversation and the discovery of new knowledge and understanding" (Alvesson & Jorgen, 2013).

2. Level of Understanding in Research in terms of Methodology

Table 3 Level of Understanding in Writing Research Methodology

		STUDENTS	
	ITEMS	**WM**	**Verbal Description**
1	I know that I need to identify a method that is going to be used in my study.	2.84	Good
2	I know that I need to determine the nature or characteristics of the respondents of my study.	2.75	Good
3	I know what I need to identify a sampling procedure that will be used in my study.	2.75	Good
4	I know that I need to identify the research methods, approaches and design used throughout my study.	2.74	Good
5	I know that I need to identify or create criteria used to choose respondents.	2.76	Good
6	I know that I need to identify which research instrument should be used in my study.	2.73	Good
7	I know that I need to identify the statistical treatment that is going to be used in the study.	2.69	Good
8	I know that I need to identify what technique or process is going to be used in order for me to gather information.	2.72	Good
9	I know I must be aware of the rationale for why a specific methodology is being used.	2.72	Good
10	I know that I need to be aware of the background and rationale of methodologies that are used in the study.	2.68	Good

11	I know that I need to perform some statistical computation with the aid of programs and applications.	2.68	Good
12	I know that I need to double-check the solutions to have clear findings.	2.76	Good
13	I know that I need to observe the seal of confidentiality.	2.75	Good
14	I know that I need to find out data that would back up the results from my research subject.	2.70	Good
15	I know that I need to be familiar with all methodological approaches used in my study.	2.80	Good
	Overall Weighted Mean	**2.74**	**Good**

Legend: 1.00-1.74 – Poor; 1.75-2.49 – Low; 2.50-3.24 – Good; 3.25-4.00 – Excellent

Table 3 presents the data gathered on the understanding of the respondents in writing the research chapter 2. As can be gleaned from the table, the student respondents responded to the item stating "I know that I need to identify a method that is going to be used in my study", obtaining the highest weighted mean of 2.84. It was also followed by an item stating, "I know that I need to be familiar with all methodological approaches used in my study," with a weighted mean of 2.80.

The responses of the student respondents unanimously fall under the verbal interpretation of "Good". It means that their understanding is extensive, and there are only some items that the students are not aware of regarding writing research, particularly on Methodology.

Based on the Journal of Research Guide (2018), "the methods section describes actions to be taken to investigate a research problem and the rationale for the application of specific procedures or techniques used to identify, select, process and analyze information applied to understand the problem, thereby allowing the reader to critically evaluate a study's overall validity and reliability".

3. Level of Understanding in Research in terms of Presentation, Interpretation, and Analysis of Data

Table 4 Level of Understanding in Writing Research Presentation, Interpretation, and Analysis of Data

		STUDENTS	
	ITEMS	**WM**	**Verbal Description**
1	I know that I need to present the results and findings of my study.	2.79	Good
2	I know that I need to follow the flow on how to present the data being treated.	2.73	Good
3	I know that I need to present my findings clearly using words that can be easily understood.	2.72	Good
4	I know that I need to deliver details of my findings that are scholarly in nature.	2.68	Good
5	I know that I need to research further in order to support my interpretation and analysis.	2.70	Good
6	I know that I need to present tables in order to show clearly all data being treated and gathered.	2.68	Good

7	I know that I need to distinguish data or findings which is considered key findings of my research.	2.70	Good
8	I know that I need to show findings that are only based on the facts that I have gathered.	2.66	Good
9	I know how to provide graphs illustrating the results of the research.	2.65	Good
10	I know how to gather references to support my findings.	2.69	Good
11	I know that I need to point out some ideas that could also be a subject for further studies.	2.64	Good
12	I know that I need to be aware of the relationship between current and previous studies.	2.70	Good
13	I know that I need to analyze only significant findings and not simply repeat the results section with more commentary.	2.66	Good
14	I know how to point out the statistical test used in obtaining the result (if applicable).	2.64	Good
15	I know that I need to observe proper English tenses.	2.68	Good
	Overall Weighted Mean	**2.69**	**Good**

Legend: 1.00-1.74 – Poor; 1.75-2.49 – Low; 2.50-3.24 – Good; 3.25-4.00 – Excellent

Table 4 presents the data gathered on the understanding of Grade 12 students in writing Chapter 3. From the table, it may be seen that the fifteen items obtained an average weighted mean of 2.69 and interpreted as "Good". Of the fifteen items, *"I know that I need to present the results and findings of my study"* obtained the highest weighted mean of 2.79; this was followed by *" I know that I need to follow the flow on how I present the data being treated"* with 2.73; *"I know that I need to present my finding clearly using words that can be easily understand"* with 2.72; *"I know that I need to research further for me to support my interpretation and analysis", "I know that I need to distinguish data or findings which is considered to be a key findings of my research"* and *"I know that I need to be aware on the relationship of the current and previous studies"* with 2.70.

The finding shows that the respondents unanimously agreed that they have a "Good" understanding when it comes to writing Chapter 3. With the overall weighted mean of 2.69 from the responses of the students, it is clear that the respondents described their understanding of writing research, particularly on "Presentation, Interpretation, and Analysis of Data", to be extensive. There were items or parts of the research work that the respondents were not aware of. Similarly, there are areas that the respondents do not give 100% attention to.

The Journal of Research Guide (2018) "strengthen the claim that the purpose of Chapter 3 is to have a scholarly discussion with the purpose of interpreting and describing the significance of findings in light of what was already known about the research problem being investigated, and to explain any new understanding or insight about the problem".

4. Level of Understanding in Research in terms of Summary, Conclusion, and Recommendation

Table 5 Level of Understanding in Writing Research Summary, Conclusion, and Recommendation

		STUDENTS	
	ITEMS	**WM**	**Verbal Description**
1	I know that I need to present a summary of my study.	2.88	Good
2	I know that I need to present logical reasoning and answers to the questions posted in my study.	2.73	Good
3	I know that I need to strengthen my discussion in order for readers to identify ideas that are material for further studies.	2.78	Good
4	I know that I also need to indicate specific measures or directions that can be taken in my study.	2.71	Good
5	I know that I need to understand the progression of the study and summarize it.	2.71	Good
6	I know that I must be aware of the scope and limit of the study for future researchers.	2.65	Good
7	I know how to figure out the answer to the main research question concisely.	2.67	Good
8	I know that I need to present the conclusion of my study.	2.75	Good
9	I know that I need to explain the main discovery of my study.	2.69	Good
10	I know how to distinguish the important findings that should be included in the summary.	2.69	Good
11	I know the relevant recommendations made for future researchers.	2.69	Good
12	I know how to recognize what must be included in the conclusion.	2.65	Good
13	I know that I need to figure out what must be written in the summary of my study.	2.65	Good
14	I know that I need to determine the ideas to form a conclusion.	2.63	Good
15	I know how to explain new understanding or fresh insights about the problem after taking the findings into conclusion.	2.69	Good
	Overall Weighted Mean	**2.70**	**Good**

Legend: 1.00-1.74 – Poor; 1.75-2.49 – Low; 2.50-3.24 – Good; 3.25-4.00 – Excellent

Table 5 presents the data gathered on the understanding of the respondents regarding their understanding of writing Chapter 4.

From the table, it may be seen that the fifteen items obtained an average weighted mean of 2.70 and interpreted as "GOOD". Of the fifteen items, "I know that I need to present a summary of my study" obtained the highest weighted mean of 2.88 and was labelled as "Good". This was followed by "I know that I need to strengthen my discussion for readers to identify ideas that is material for further studies." with 2.78; "I know that I need to present conclusion of my study." with 2.75; "I know that I need to present logical reasoning and answers to the question posted in my study." with 2.73; "I know that I need also to indicate the specific measures or directions that can be taken on my study." and "I know that I need to

understand the progression of the study and summarize it." with 2.71.

All of the student respondents agreed that they have a "Good" understanding of Chapter 4, which means that their understanding is extensive. There are items which the respondents are not aware of. Similarly, there are areas that the respondents do not give 100% attention to.

Understanding Chapter 4 is necessary, though a higher level of understanding is required to have a better presentation of summary, recommendation, and conclusion, since this chapter appreciates having a severe perseverance and ability to construct ideas effectively.

In order to complete the study, a researcher must survive and surpass this final challenge, which is dealing with the data and its respective findings. It can be overcome through a strict focus and interest on the chosen topic from the start of conducting the research up to the final stage of presenting data (Suryani, Muspawi & Aprillitzavivayarti, 2023).

IV. CONCLUSIONS AND RECOMMENDATIONS

1. Students demonstrated a good level of understanding in writing Chapter 1 of the research, particularly in identifying the urgency, alignment of literature, and scope of the study, though some areas still require deeper attention to ensure a well-founded research foundation.

2. Students showed a good level of understanding in writing the research methodology chapter, particularly in identifying appropriate methods, sampling procedures, and research instruments, although some methodological concepts still require further clarification and reinforcement.

3. Students exhibited a good level of understanding in presenting, interpreting, and analyzing research data, particularly in organizing findings and using supporting visuals, though some aspects still need greater attention to ensure depth and scholarly interpretation.

4. Students demonstrated a good level of understanding in writing the summary, conclusion, and recommendation of their research, particularly in presenting findings and formulating insights, though some aspects still require greater focus to ensure clarity and completeness in final outputs.

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Impact of Abusive Leadership on Employee Job Output

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Abstract *— The research study examines how emotional exhaustion and work engagement act as mediating factors. They serve as intermediary links in the chain of events between abusive leadership and employee job output. The study aims to understand the extent to which emotional exhaustion mediates the negative impact of abusive leadership on job output, as well as how work engagement can act as a counteractive force. Additionally, the study has explored the moderating role of mindfulness. Mindfulness refers to the practice of being present and fully aware of one's thoughts, feelings, and surroundings without judgment. Mindfulness can act as a protective factor for employees exposed to abusive leadership. It may help employees cope with the negative emotions associated with abusive behaviour and reduce the extent to which emotional exhaustion affects their job output. Mindfulness could also enhance work engagement by promoting resilience and a positive outlook, even in the face of challenging leadership. In summary, this research aimed to uncover the intricate relationship between abusive leadership, emotional exhaustion, work engagement, and mindfulness. By examining how these factors interact, the study provides insights into how organizations can mitigate the negative effects of abusive leadership on employee job output and well-being. The analysis employed SPSS, and the results indicated correlation between the two mediators.*

Keywords *— **Abusive supervision, work engagement, emotional exhaustion, mindfulness, job performance***

Introduction

The impact of abusive leadership on employee job output is influenced by several factors that interact in complex ways. This study examines how these factors come together, with a particular focus on the mediating role of emotional exhaustion and work engagement, as well as the moderating role of mindfulness. Abusive leadership refers to supervisors or managers who engage in behaviours' that are harmful, demeaning, or disrespectful towards their employees. These behaviours can create a hostile work environment, leading to negative outcomes for employees. One of the main ways in which abusive leadership affects employee

job output is through emotional exhaustion. Emotional exhaustion refers to a state of extreme fatigue and burnout caused by prolonged exposure to stressors, such as abusive behaviour from leaders. When employees are consistently subjected to abusive leadership, they may become emotionally drained, leading to reduced motivation, productivity, and overall job performance.

On the other hand, work engagement is the opposite of emotional exhaustion. It refers to employees' enthusiasm, involvement, and dedication to their work. Abusive leadership can severely diminish work engagement by creating a negative emotional climate and eroding employees' sense of purpose and commitment to their tasks. Reduced work engagement can directly impact job output, as employees are less likely to invest their energy and effort into their work.

Organizational psychology and management research have given a great deal of attention to the complicated and diverse problem of the effect of abusive leadership on employee work performance. When managers or supervisors act in a hurtful, humiliating, or contemptuous manner toward their employees, it is referred to as abusive leadership. These actions can include verbal abuse, humiliation in public, excessive supervision, unfair treatment, and denial of opportunities or resources. Abuseful leadership has a complex link with how well employees perform on the job, and it can take many different forms. Here is a thorough explanation of how poor leadership can affect workers' ability to execute their jobs:

Psychological Stress and Well-being: Employees experience psychological stress due to the toxic work environment that abusive leadership fosters. Employees' wellbeing and mental health deteriorate when they are frequently exposed to harmful practices. Such stress can result in emotional tiredness, anxiety, and even despair, all of which have an impact on one's ability to think clearly, make decisions, and execute their work as a whole.

Reduced Motivation and Engagement: Employees who work under abusive managers frequently lose motivation and interest in their jobs. Lack of excitement and passion for work can result from a persistent dread of criticism or punishment. Employee commitment to their roles decreases when they feel unappreciated and unsupported, which lowers effort and job effectiveness.

Job Satisfaction and Organizational Commitment: Abusive leadership weakens organizational commitment and job happiness. Employees who experience poor treatment from their managers are less likely to feel devoted to the organization's objectives and satisfied with their work. Their motivation to go above and above may be impacted by this lack of alignment and loyalty, which could affect how well they perform at work.

Impaired Communication and Collaboration: Ineffective teamwork and communication are frequently caused by abusive leadership. To reduce exposure to unfavourable interactions, employees may avoid communicating with their managers or fellow workers. This impedes communication, the exchange of ideas, and teamwork, all of which are necessary for performing one's job well.

Physical Health Implications: Long-term contact with abusive leadership may also have negative effects on one's physical health. Stress-related health difficulties can have a negative impact on a worker's capacity for effective and efficient task completion, such as sleep disruptions, headaches, and cardiovascular problems.

Inhibiting Creativity and Innovation: Environments that value risk-taking and open communication foster creativity and innovation. Because they are afraid of criticism or retaliation, employees who work under abusive leadership are less willing to voice their opinions. As a result, there are less opportunities for innovation and original thinking, which has an impact on job performance.

Turnover Intention and Absenteeism: Employees who are subjected to abusive leadership are more likely to have higher intents to leave their jobs and be absent more frequently. As a result of stress-related health issues or a desire to leave the toxic atmosphere, they might actively look for different employment options or take time off from work. Absenteeism and high employee turnover impede productivity and lower overall job performance.

Negative Role Modeling: Negative leadership behavior sets a bad example for workers. When CEOs act disrespectfully, it may set a precedent for similar behavior throughout the company. Employees might imitate these actions, which would reduce teamwork and overall productivity.

Abuse in a position of leadership has a significant and wide-ranging effect on how well employees perform at work. It has an impact on workers' physical and mental health as well as their motivation, engagement, satisfaction, and teamwork. Abusive leadership can have a detrimental impact on team dynamics, innovation, and the success of the organization as a whole, in addition to lowering individual job performance.

Emotional Exhaustion

In the workplace, emotional exhaustion is a psychological condition marked by feelings of tiredness, fatigue, and emotional drain brought on by extended exposure to numerous stressors and expectations. It is a crucial aspect of burnout, a syndrome that develops when people are subjected to ongoing stress at work. Employee well-being and the efficiency of companies as a whole can both be significantly impacted by emotional weariness. The following is a thorough explanation of emotional weariness at work:

Causes and Stressors: Most often, a number of issues connected to the workplace combine to cause emotional tiredness. High workloads, excessive job demands, irrational expectations, time restraints, long hours, a lack of autonomy, unclear roles, interpersonal difficulties, and the impression that one has no control over one's workplace are a few examples. The continual exposure to other people's emotional needs in emotionally taxing jobs like healthcare and customer service can also cause emotional weariness.

Symptoms and Signs: Employees who are emotionally exhausted may display a variety of physical and psychological symptoms. Chronic fatigue, decreased energy, irritability, mood fluctuations, trouble concentrating, memory issues, diminished motivation, and a sense of cynicism or detachment from work-related duties may be some of these symptoms. Physical symptoms including muscle tension, headaches, and sleep problems can also appear.

Burnout and the Three Dimensions: One of the three components of burnout, along with decreasing personal accomplishment (feeling unsuccessful and incompetent in one's job function) and depersonalization (having a detached and impersonal attitude toward others), is emotional weariness. The primary dimension of burnout is emotional depletion, which frequently precedes the other two dimensions.

Impact on Performance: Work performance is directly impacted by emotional weariness. Employees who are emotionally spent may have impaired cognitive function, which affects their capacity for concentration, attention, and decision-making. This may lead to mistakes, lowered productivity, and lower-quality work. Additionally, emotional tiredness might impair one's ability to be creative and solve problems.

Interpersonal Dynamics: Employees that are emotionally spent may have trouble interacting with others. They might struggle to relate to co-workers, clients, or customers, which could damage relationships. Conflicts, broken down communication, and strained teamwork can result from this, which can further affect overall workplace effectiveness.

Health Implications: The effects of emotional tiredness might extend outside of the workplace and into a person's personal life. Anxiety, depression, cardiovascular troubles, and decreased immune function are just a few of the physical and mental health concerns that can result from long-term stress and emotional strain. These health issues may make it even more difficult for a person to do their job well.

Prevention and Coping Strategies: Organizations can prevent and treat emotional tiredness by taking proactive measures. These include building a friendly and happy work environment, encouraging work-life balance, giving resources for stress management and emotional well-being, providing training in resilience and coping skills, and making sure that employees have some control over their activities.

Work Engagement

A positive and energizing mental state known as "work engagement" is defined by a deep connection to and involvement in one's duties and tasks at work. Due to its effects on employee well-being, job performance, and overall organizational success, it is a notion that is frequently explored in organizational psychology and management research. A strong sense of fulfilment, passion, and dedication to one's work are all characteristics of work engagement, which goes beyond simple job contentment. Three main elements make up work engagement:

Vigor: High degrees of vigor, mental toughness, and enthusiasm are shown in this component. Employees who are energized are enthusiastic about their work, have a positive outlook, and attack problems with a feeling of resolve.

Dedication: Being truly committed to one's work and having a strong feeling of the importance of what one does are two characteristics of dedication. Employees that are engaged are proud of their accomplishments and find purpose in their work.

Absorption: Being completely absorbed and involved in one's work duties is referred to as absorption. When workers are fully engaged in their work, they become time-absorbed and experience a state of flow in which their abilities are perfectly matched to the tasks at hand.

Mindfulness

The practice of being completely present and conscious of one's thoughts, feelings, and surroundings in a non-judgmental manner while performing work-related duties is known as mindfulness in the workplace. It entails practicing present-focused awareness, which has a number of advantages for both people and businesses. Practices

of mindfulness have grown in popularity as a tool to improve productivity, establish a healthier work atmosphere, and improve well-being. A thorough explanation of mindfulness in the workplace is provided below:

Core Principles of Mindfulness are:

Present-Moment Awareness: Being mindful entails concentrating on the present moment without thinking about the past or the future. It helps people to focus their attention on what they are doing right now.

Non-Judgmental Attitude: People who practice mindfulness are encouraged to be objective observers of their thoughts, feelings, and experiences. This passive attitude encourages self-acceptance while minimizing self-criticism.

Open Awareness: People who practice mindfulness are encouraged to be receptive to whatever comes to mind, good or bad, without attachment or aversion.

Job Performance

The degree to which an individual successfully completes the tasks, responsibilities, and duties related with their job function within an organization is referred to as their "job performance." It is an important indicator of how much an employee contributes to the overall objectives and success of the company. A number of variables, such as an employee's talents, abilities, motivation, workplace environment, and alignment with the organization's values and goals, affect how well they accomplish their jobs. Here is a thorough justification of work performance:

Components of Job Performance include:

Task Performance: The technical elements of the job are the emphasis of this section. It comprises the precise duties, obligations, and responsibilities listed in the job description for the individual. The way a worker does a task reveals how successfully they carry out their primary responsibilities and adhere to organizational standards.

Contextual Performance: Contextual performance, also referred to as organizational citizenship behaviour, includes actions that go above and beyond the conventional work responsibilities. It comprises actions that improve the working environment, like assisting co-workers, volunteering for projects, and being a good team player.

Research Problem

The most significant difficulties that Pakistan's construction industry will need to overcome in the next several years are those that involve the emotional weariness of workers. The building and construction business is often regarded as one of the fastest-evolving and most prosperous sectors on a global scale. Over the course of the last several years, Pakistan's construction industry has grown to become a significant economic sector. The abusive supervision that adversely impacts job performance by decreasing employees' work engagement and emotional tiredness is the primary factor contributing to the intense rivalry that exists in the construction industry.

Research Gap

This study aimed to assist professionals or supervisors in identifying gaps in their organizational performance and provide ideas on how to resist abusive supervision in their organization in the construction industry in order to enhance job performance. This research was carried out in order to help improve job performance. If an employee is emotionally exhausted from the harsh monitoring they get from their employer, they will be more prone to engage in the industry. This, in turn, will have an effect on the person's performance

on the job. In a similar vein, it will provide guidance to companies on how to improve their marketing efforts by using construction-related advertising rules in order to engage their audience. In conclusion, this research helped businesses improve their supervision in terms of work engagement, emotional exhaustion, and job performance by using empirical evidence to guide them through a review of their current practices and the development of new strategies. It also contributed to and assisted business leaders in improving their supervision in these areas.

Purpose of the Research

The goal of this research was to delve into two interconnected processes that contribute to the negative correlation between working under abusive supervision and productivity on the job. There is a negative impact on health (in the form of increased emotional weariness) and a negative impact on motivation (in the form of decreased job satisfaction) (lower work engagement). In addition to this, it investigated the ways in which workers' mindfulness, especially as it manifests in its attention–awareness component, may be able to halt this potentially damaging process. The research aimed to learn how followers rate their leaders' effectiveness and how their experiences with ineffective leaders contributed to stress on the job. Insights from this study on abusive monitoring in business processes will benefit Pakistan's construction sector. Insights from this research on the relationship between emotional weariness and employee involvement in the workplace are useful to those in the construction sector. This study provides important insight for business owners and managers about the relationship between mindfulness and abusive management.

Research Objectives

Following were the main objectives this research:

1. Finding out the effects of abusive leadership on employee job performance.
2. Determining the link between abusive leadership and job performance through emotional exhaustion as a mediator.
3. To determine the influence of employee work engagement as a mediator between abusive leadership and job performance.
4. To determine the influence of mindfulness as moderating variable of the connection between abusive leadership and work engagement for achieving enhanced job performance.

Research Questions

RQ 1: Is there any effect of abusive leadership on employee job performance?

RQ 2: Is it possible to determine the link between abusive leadership and job performance through emotional exhaustion as a mediator?

RQ 3: How to determine the influence of employee work engagement as a mediator between abusive leadership and job performance?

RQ 4: How to determine the influence of mindfulness as moderating variable of the connection between abusive leadership and work engagement for achieving enhanced job performance?

Academic Contribution

The knowledge contribution of this research is on the mediating role played by employees' level of engagement and dedication on the relationship between emotionally draining work environments and abusive managers. In addition, the purpose of this research was to examine the effects of abusive supervision on companies in the Pakistani construction sector by analyzing the relationship

between employees' emotional tiredness and their work output. This study provides useful information for the construction industry by shedding light on the causes and consequences of abusive supervision and providing recommendations on how to prevent it. The findings of this study adds to our knowledge of the negative effects of abusive supervision on workers' motivation and productivity.

Practical Contribution

This study has important implications for the construction industry in Pakistan and for organizations in this field that are planning to launch soon. Findings from this study helps employers better understand the impact of abusive supervision on employee performance, the role that emotional exhaustion and disengagement from work play in influencing this relationship, and the impact of employees' mindfulness on their reactions to abusive supervision. This study is helpful to both company owners and workers since it identifies which small businesses have weak supervision systems and may benefit from restructuring such systems to boost employee engagement and productivity.

Literature Review

Studies have shown that emotional exhaustion mediates workplace morale is lowered when workers are subjected to abusive management (Aryee, et al., 2008). In light of this, the major objective and The purpose of our study was to look for evidence of a mediating effect. One of the hallmarks of burnout is a sensation of emotional depletion, or emotional tiredness (Maslach, C., & Jackson, S. 1981). Our argument is based on the idea that workers are profoundly impacted by their superiors' actions, and that abusive supervision may have a negative impact on business results (Shin, Y.; Hur, W., 2020). Due to the supervisor's position of control over employees' human resources (Sliter, et al., 2012), abuse from above may have a significant effect on workers' emotional weariness and productivity (Shin, Y.; Hur, W., 2020). Employees who provide frontline services are often used as a "punching bag" by their superiors. They are the ones that consumers go to with their concerns. Meanwhile, their superiors and colleagues are constantly observing and assessing their actions at work, leaving them open to unfair treatment. Despite growing body of research indicating that frontline workers face a wide variety of interpersonal pressures (Sliter, et al., 2012; Al-Hawari, et al 2020).

Anxiety, frustration, resentment, and exhaustion are all examples of emotional states associated with work that have been linked to the onset of psychological conflict and, perhaps, physical illness (Huerta-Franco et al., 2013). Leaders have been recognized as a significant source of negative emotions and work unhappiness, and hence an employee's mood or emotional experience may also favorably or adversely affect perceptions of stress, leadership, and results (Defoe, 2012). Unproductive leadership styles were linked to employees' negative feelings, which in turn raised their stress and lowered their work satisfaction (Defoe, 2012). Role conflict, role ambiguity, and role overload are all sources of tension in the workplace, and they've been linked to negative outcomes like (a) lower levels of psychological health, (b) decreased attitudes towards work (such as contentment, discontentment, commitment to the team or organization, and burnout) (Beheshtifar & Nazarian, 2013; Newt).

Employees can get help in coping with difficult work conditions like overload with attention awareness mindfulness is already found in previous research (conducted by Montani et al., 2020) or research on emotional challenges at work (research was conducted by Haun et al., 2018). JD-R model is being used to see if this personal resource can help in diminishing the problems additional work requirement, authoritarian management style (Huang et al., 2019). Mindfulness is considered a broaden concept consisting of five parts (being aware of, describing, acting on, not judging, and not reacting to one's own inner experiences); (Moskal et al., 2020), however considerable perspective, Employees' "greater awareness and understanding of [their] recent perspective or present reality" is better captured by the MAAS (Mindful Attention and Awareness Scale). "Awareness entails feeling and observing reality," write Brown and Ryan (2003), "and focused attention leads awareness to particular components of the encountered reality" (highlighted by Leroy et al., 2013).

In very stressful work environments, employees may be less productive and efficient (Nguyen et al., 2018; Loi et al., 2016). When an employee faces obstacles on the job, especially if those obstacles are caused by the superior they answer to and who bears ultimate accountability for the employee's professional development and advancement (e.g., a hostile or abusive supervisor), the employee may become increasingly frustrated (Huang et al., 2019; Avey et al., 2015). It is well accepted that abusive supervision is a damaging practice that has negative consequences for both workers and employers (Lin, Wang, & Chen, 2013; Schat, et al., 2006; Tepper, 2007). Workers' job satisfaction (Lin et al., 2013; Tepper, 2000; Tepper, Duffy, Hoobler, &Ensley, 2004), commitment to the organization (Aryee, et al., 2007; Duffy, Ganster, & Pagon, 2002; Schat et al., 2006), and productivity all suffer when their supervisors are abusive (Aryee, Sun, Chen, & Debrah, 2008; Harris, Kacmar, & Zivnuska, 2007; Shoss, Eisenberger, Restubog, & Zagenczyk, 2013; Wheeler, Halbesleben, & Whitman, 2013).

Leaders that are abusive to their followers' exhibit hostility, use insulting language, and have little regard for their followers' welfare or growth (illustrated by Kacmar et al., 2015; Yu et al., 2016). Because of the serious risk it poses to their workers, businesses constantly worry about the possibility of being led by an abusive boss. Workers associate their superiors with the company and look to them as symbols of the company (Biron & Bamberger, 2012). Employees who have a bad boss often end up blaming their company (Shoss et al., 2013) since their abusive supervisor has made them feel unappreciated and disadvantaged in their careers (Aryee et al., 2007).

Employees who are led abusively fear for their employment (demonstrated by Schaubroeck et al., 2016; Yang et al., 2020), consider all their efforts will go unappreciated, and try to avoid coming to work as much as possible (illustrated by Kacmar et al., 2015; Peng et al., 2014).

As a result, harmful supervision has the potential to reduce civic behaviors including pro-social voice, innovation, and information sharing (observed by Gu et al., 2016; Gregory et al.. 2016; Gregory et al., 2013). "(illustrated by Kim et al.., 2016)" insufficient internal drive (Ding&Tariq, 2018), attachment at extreme emotional level (Yu et al., 2016), leader-member interactions (Xu et al.., 2012.;Peng et al., 2014), and attitudes of moral leadership all moderate having an abusive supervisor has a negative effect on productivity. (Kacmar et al., 2015). We suggest include workers' degrees of emotional

weariness and job engagement to increase the study's overall breadth (Mihail and Kloutsiniotis, 2016), two measures of occupational well-being, can be used to link the effects of abusive leadership on employees' productivity on the job. According to (Boon and Kalshoven, 2014: 406), According to the authors, "work engagement may be defined as a good, rewarding, job-related condition of a person having a lot of vitality" linked by three interconnected characteristics of vigor, devotion, and absorption. Feeling emotionally overextended at work due to emotional exhaustion is a significant part of work exhaustion (De Clerck et al., 2018). Dedication and zeal for one's job may be summed up by one's willingness to put in long hours on tasks associated with that work; this kind of enthusiasm for one's work is shown in one's ability to focus intently on the tasks at hand, which is a good indicator of one's level of absorption (Schaufeli and Bakker, 2010). Abusive management is likely to have a detrimental impact on employees' work engagement, which can be summed up as a sense of belonging to one's workplace and loyalty to one's employer (Boon & Kalshoven, 2014; Macey & Schneider, 2008). Barnes et al., (2015) investigate the interplay between emotional tiredness and job participation in the context of abusive supervision to gauge their relative efficacy as protective mechanisms associated to workers' mental well-being and inspiration (Kloutsiniotis & Mihail, 2016; Moliner et al., 2008). To examine how mental tiredness and enthusiasm for one's job relate to one's sense of occupational well-being, we will use JD-R Model of Workplace Demands and Capabilities (Heuven et al., 2006; Schaufeli and Bakker, 2004). To be more precise, we demonstrate that employees' exposure to abusive supervision, as a demanding job condition (Huang et al., 2019; Wang, 2019), decreases job performance through (1) a negative health process, in the form of greater compassion fatigue, and (2) an incentive reduction process, as clearly apparent in lower job involvement (Akkermans et al., 2013).

We'll go with the latter viewpoint on the grounds that the mindfulness skill of paying attention makes us more resilient in the face of difficult work scenarios (highlighted by Martin et al.,.2018.; Weintraub et al., 2019). Mindfulness, or attention-awareness, is a resource that mitigates the negative impact of a significant work requirement (abusive supervision) on job performance via emotional weariness. Although there are likely many other personal resources available to employees who wish to shield themselves from the perils of abusive supervision, this paper will focus on mindfulness due to the practical value we have found in investigating its widespread usability and adaptability thanks to mindfulness-based intervention programs (Jamieson and Tuckey, 2017). This research will investigate the possible links between abusive leadership practices and poor employee performance, with a focus on the mediating roles of emotional tiredness and lack of work engagement (as studied by Bakker and Demerit in 2017; Garcia et al., 2017). Is it because they are overworked and/or they just don't want to accomplish their tasks that managers raise this issue, or is it something else entirely? Both of these elements highlight the fact that victims of abusive supervision sometimes face double punishment. A bad work environment may become even worse when it causes physical harm or a loss of motivation to complete job duties, or when it's compounded by the distressing emotions that result from being insulted by organizational leaders. We also address the demand for the sake of using a contingency model in research methodologies to investigate the

effects of abusive leadership (quoted by Lee et al…, 2018; Tariq and Ding, 2018; Xiao et al., 2020). There was petty doubt in the valuable study as to whether or not poor leadership or influencing personal qualities, self-restraint being one example (studied by Xiao et al.., 2020) prevented employees from working successfully. This research might be used by businesses to aid workers in enduring the challenges imposed by verbally abusive supervisors by taking into account decreasing value of being present in the moment. They should appreciate workers to pay attention to and become more aware of the here and now (as mentioned by Brown et al…, 2007; Leroy et al…, in 2013). We propose more Consistent with earlier results on its impact on how workers cope with numerical and psychological pressures at work (Haun et al., 2018) or polytonicity, we hypothesis Mindfulness with attention-awareness serves as a defensive and buffering mechanism. Employees who pay close attention to their day-to-day situations may be more likely to see their abusive supervisors as unjust, according to some data (Burton and Barber, 2019; Weintraub et al., 2019).

The JD-R paradigm explains the connection between toxic management and job performance, as well as the parts played by burnout and dedication to one's profession (Bakker and Demerouti, 2007). Workplace pressures are identified as a source of stress and emotional weariness in this model's definition of (1) Health Affecting Process. (2) The process of motivation, which describes how individuals may be inspired to show their full potential in the workplace by making use of the tools provided by their employer (Akkermans et al., 2013; Schaufeli and Bakker, 2004).

While the JD-R approach highlights the positive impact of career opportunities on employee engagement, it also represents the potential for stressful work requirements might have a negative impact on employee commitment to their jobs (quoted by Garcia et al.., 2017...; Kunte and Rung Ruang., 2019; Tadic et al., 2015). Specifically, this further development in the JD/R model accepts One prominent kind of constraining demand is abusive supervision, which is interpreted as frustrating unrealistic expectations that are likely to impede development, education, and the attainment of objectives, such that unrealistic annoying expectations must be adversely connected to involvement and can produce frustrating and destructive feelings and unresisting emotion-focused managing styles that exhibit giving up and decreased employee engagement. (Crawford et al., 2010) Worker disengagement has been shown in previous JD-R model implementations when workers are subjected to frustrating expectations such as disagreement over roles (studied by Breevaart & Bakker. 2018), ambiguity of roles (Kunte & Rung Ruang, 2019), or red tape that's out of control (Tadic et al., 2015). Based on the existing literature, it is hypothesized that abusive supervision lowers job performance because it has an effect on workers' emotional tiredness and work engagement. (Huang et al., 2019) The JD-R model, in its previous iterations, has also acknowledged the detrimental effects of emotional tiredness and disengagement on performance (e.g., Bakker and Bal, 2010; Rhee et al., 2017).

Personal factors, such as employee hold a positive attitude (indicated by Loi et al…, 2016), versatility (De Clercq.., 2017), or consciousness (observed by Doorn and Hülsheger.., 2015), are also considered by the JD-R model as influencing employees' reactions to negative behavior (Bakker and Demerouti, 2007). Workers whose emotions are

mitigated by access to personal resources are more likely to be effective. Here, the JD-R model specifies how one's own resources, in addition to those made available by one's employer, might mitigate the potentially harmful impacts of one's employment. Mindfulness, or the capacity to pay attention in the now and now (Brown & Ryan, 2003), has been advocated as a resource that might help employees deal with abusive leadership in a more manageable way, leading to less burnout and more enthusiasm in the workplace (Scheuer et al., 2016). Consequently, using a personal resource like mindfulness might help you cut down on job-related activities like emotional weariness and work engagement (Bakker and Demerouti, 2007).

Because of this, two primary dynamics may be proposed: First, the relationship between abusive supervision and performance at work emerges from the interaction of emotional weariness and task involvement. Second, it is possible to propose mindfulness as a potential shield, so that (1) the association between abusive leadership and increased emotional tiredness at work and reduced job involvement is weaker, and (2) this association between these forms of professional conduct and decreased work performance is weaker.

Abusive peer behavior, emotional weariness, and job uncertainty are all brought on by abusive leader behavior. Employees who experience mistreatment from their immediate superiors may be inspired by their peers to participate in unethical behavior as a reaction. This can leave them feeling emotionally spent and raise fears about their job security (José E. Muñoz, 2022).

Another study discovered that psychological anguish and exhaustion both predict the intention to leave. Burnout and the desire to quit are related in part through psychological discomfort. The relationship between burnout and psychological distress is moderated by financial well-being, making it stronger for workers with high income prospects. However, the relationship between burnout and intention to quit is unaffected by financial well-being; burnout always results in the desire to leave one's job (Asier Baquero, 2023).

Similar to how abusive peer behaviour, emotional weariness, and job instability are brought on by abusive boss behaviour. Employees who experience mistreatment from their immediate superiors may be inspired by their peers to participate in unethical behaviour as a reaction. This can leave them feeling emotionally spent and raise fears about their job security (Miao Li, 2022). Deep acting can be made less detrimental for leader behaviour because of the draining nature of emotional Labor in leading and the significance of leader mindfulness as a boundary condition. In addition to the moderating effect of leader mindfulness, emotional Labor methods (surface acting and deep acting) deplete leaders' resources for self-control in order to anticipate harsh oversight (Mikaila Ortynsky, 2023).

Research Approach and Methodology

Due to the interpretive character of this research, a quantitative perspective was considered essential. The inductive approach to studying the connection between abusive conduct and later employment loyalty, commitment, and performance was recognized in the proposed study. There are two primary types of research: quantitative and qualitative. In-depth interviews and focus groups are employed in qualitative research (Bryman & Burgess, 1999). (Bryman& Burgess,1999). In qualitative research, open-ended questions are applied to get a rapid understanding (Creswell, 2013). In quantitative research the essential part of

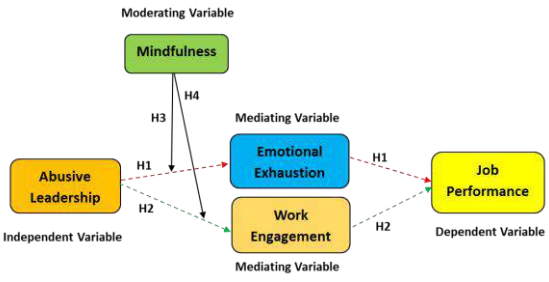
investigation is reliability and validity of concept (Creswell, 2013). (Creswell, 2013). This research was quantitative in type and was based on the post positivist way of thinking, as well as the premise of observational learning and two stage stream correspondence assumptions. This was a deductive examination in which crucial data was obtained utilizing a leading overview/questionnaire of quantitative approach (structured questionnaires). The study's subject matter was to collect data from employees and their managers/supervisors on the influence of rude behaviour from Pakistan's construction sector. Past research work relating to the topic was also utilized as a reference to better comprehend the prior work and relevance of the subject. Main data collection was largely quantitative (close ended questionnaire 5 Likert scale were employed in this research).

Data was collected from FWO and Nespak. 300 questionnaires were distributed out of which 200 were selected as valid. Information will be obtained from the Pakistani construction industry. The study was divided into three phases. Data collection was done during a period of time that was neither too long nor too short to introduce the possibility of reverse causality due to unexpected internal or external occurrences. To facilitate survey administration, the language English will be chosen. In order to safeguard the rights of participants and remove the possibility of social appeal and influence, many steps will be taken. The survey will include invitation statements, and respondents will be free to reply or not; all responses will be treated in confidence.

The study will be run using SPSS for processing, which will yield accurate findings. The study will be evaluated to come up with an outcome and analysing the impact. The reliability test will be used to determine the model's validity, and Cronbach Alpha will be used to analyse the validation. The key hypotheses will be analysed using a co relational approach. Regression analysis will be the method used to compile the statistical findings. Multiple regression analysis will follow the correlation analysis. Using multiple regression analysis, researcher will try to find the independent variable best predicting the dependent one. It will be chosen because it will allow for a comprehensive and parallel analysis of the variables.

A statistical method called the collinearity test, often referred to as the multi-collinearity test, will be used to evaluate the degree of linear relationship between predictor variables in a regression analysis. Multi-collinearity in a regression model is when two or more predictor variables have a high correlation with one another. Collinearity tests will be used to determine the degree of multi-collinearity among predictor variables and to quantify it. Understanding how particular predictor factors affect the dependent variable while maintaining the other variables constant is the aim of a regression study.

Shown below is the conceptualized model:



Conceptualized Model

Independent Variable

- Abusive Leadership

Moderating Variable

- Mindfulness

Mediating Variables

- Emotional Exhaustion
- Work Engagement

Dependent Variable

- Job Performance

Following were the developed research hypothesis:

Hypothesis 1 (H1): Emotional exhaustion of employees influences the connection between abusive leadership and job performance.

Hypothesis 2 (H2): Work Engagement mediates the effect of abusive leadership on job performance.

Hypohesis 3 (H3): That employees who regularly engage in mindfulness would be less affected by the negative association between working under abusive leadership and emotional exhaustion.

Hypothesis 4 (H4): Employees' exposure to abusive leadership is negatively correlated with their job performance output as measured by their level of work engagement, with correlation attenuated for those with higher levels of mindfulness.

This study had few limitations. Although the suggested method intended to show promise in a construction industry scenario, the research's applicability was limited since other services may not need as much engagement. Therefore, the proposed model may be used in a wide range of service/product settings, with the level of moderator engagement serving as a determining factor. Another cause for concern was the possibility that the emotional tiredness experienced by the employees in the sample was not universal. This issue may be resolved by expanding the scope of future studies to include other causes of fatigue in the workplace.

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Enhancing Students' Success: An In-Depth Analysis of Support Systems and Strategies for Facilitating Supplemental Short Soft Skill Courses and Micro Badges

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Abstract *— This descriptive research analyzed the support systems and strategies for facilitating supplemental short soft skills and micro badges of the 113 College of Hospitality and Tourism management students of Wesleyan University-Philippines. The profile of the respondents was described, as well as their short-term soft skills and micro badges earned. Additionally, support systems by the university and strategies employed by service providers were also explored. The study found that the large majority of respondents are 22-year-old female BSHM students with a moderate weekly allowance. The respondents' top 5 earned skills are communication skills, teamwork, adaptability, time management and hospitality supervisor certificate of American Hospitality Academy (AHA), while their top 5 micro badges are Customer Service Management in Tourism and Hospitality, Travel and Tourism Supervision, Travel and Tourism Operations, Travel Geography, and Destination Analysis. Institutional support is useful for access to soft skills and micro badge programs for the respondents, but improved scheduling and convenience are necessary to facilitate greater participation. Lastly, the strategies offered by the service providers are useful and understandable, but they should be more inspiring to encourage students to stay engaged.*

Keywords *— **College of Hospitality and Tourism Management, micro badges, short-soft skills, strategies, support systems***

I. INTRODUCTION

Soft skills such as communication, leadership, flexibility, and emotional intelligence would be instrumental in the success of students in service-oriented fields (Calabrese et al., 2018), hospitality and tourism management being one of them. Conventional classroom instruction is still an important source of knowledge; however, there is no way that it can contribute to experiential and people skills that can only be gained from actual work environments. So, institutions are starting to include short add-on courses for soft skills and micro badge courses to fill in the gap. Hence, this study intends to probe and analyze the support systems and mechanisms for effective acquisition of these skills among students in the College of Hospitality and Tourism Management (CHTM) (Subia, et al, 2022), Wesleyan University-Philippines, Cabanatuan City.

In addition, it is important to assess the strategies used by CHTM teachers and service providers to provide and market such courses. Clearer definition of the course goals, interesting and relevant material, practical applications, and ongoing feedback measures are all instances of winning strategies

(Sánchez-Mora et al., 2022). Through examining these factors, the researchers can identify the most effective teaching approaches that best motivate students and foster engagement and motivation. This will aid in the development of student-centered and more efficient skill development course delivery models (Sousa, 2018).

The incorporation of the demographic features and the perceptions of the students in the study provides an exhaustive analysis of the reception as well as the impact of such programs. Knowing the situation of the students, including their economic status and their exposure to soft skill development, can assist in assessing the influence of a number of determinants on their learning process. The feedback gathered through the questionnaire confirms the research on the students' experiences, and as proof, their authentic voices (Hailikari et al., 2022).

In the end, this research seeks to develop pertinent findings that could further enhance institutional support and pedagogic practices at CHTM and, possibly, elsewhere. By evoking both strengths and deficit areas of current systems and practices, the research will be a helpful tool for educational leaders, faculty, staff, and curriculum developers. Its findings would affect policy-making, such as resource allocation toward programs, where students will not only gain academic proficiency but also professional preparedness with the soft skills and certifications relevant to the global hospitality and tourism industry.

Statement of the Problem

This research made an in-depth analysis of support systems and strategies for facilitating supplemental short-term soft skill courses and micro badges.

Specifically, the research answered the following questions:

1. How may the Profile of the respondents be described in terms of age, sex, course, weekly allowance, short-term soft skills and micro badges earned?

2. How may the respondents describe the support systems for facilitating Short Soft Skill Courses and Micro badges?

3. How do the respondents describe the Strategies employed by Providers for facilitating Supplemental Short Soft Skill Courses and Micro Badges?

II. METHODOLOGY

A descriptive quantitative research design was employed in this study. Sirisilla (2023) asserts that "scientists and researchers use descriptive research design as a powerful tool to gather information about a particular group or phenomenon." Complete enumeration was used in this study to determine the total number of respondents. This kind of research offers a thorough and accurate picture of the traits and behaviors of a specific community or subject. For this study, all 113 students who had microbadges and short-term soft skills were selected as respondents. The tool used was created by the researchers and approved by subject-matter experts. Using Cronbach's alpha, the instrument's reliability was calculated. The instrument was found to be reliable, as indicated by the value of 0.891. The study is limited to a single year only.

III. RESULTS AND DISCUSSION

1. Profile of the Respondents

Table 1. Profile of the Respondents in terms of Age, Sex, Course and Weekly Allowance

Age	**Frequency**	**Percent**
20.00	2	1.8
21.00	26	23.0
22.00	45	39.8
23.00	21	18.6
24.00	12	10.6
25.00	4	3.5
26.00	3	2.7
Total	113	100.0
Sex	**Frequency**	**Percent**
Male	44	38.9
Female	69	61.1

Total	113	100.0
Course	**Frequency**	**Percent**
(BSTM)Bachelor of Science in Tourism Management	49	43.3
(BSHM)Bachelor of Science in Hospitality Management	61	54.0
(BSND)Bachelor of Science in Nutrition and Dietetics	3	2.7
Total	113	100.0
Weekly Allowance	**Frequency**	**Percent**
P500 to less than 1000	11	9.7
P1000 to less than 1500	32	28.4
P1500 to less than 2000	18	15.9
P2000 to less than 2500	26	23.0
P2500 and above	26	23.0
Total	113	100.0
Mean Allowance	P1870	

Table 1 presents the profile of the respondents in terms of age, sex, course and weekly allowance. It can be observed on the table that 45 (39.8%) of the respondents are 22 years old, 69 (61.1%) are females and BSHM students and have a mean allowance of P1870.

This suggests that many of the participants are likely in their final years of college, possibly with more academic and life experience. The age distribution may also reflect a maturity level that could influence their perspectives and decision-making. The average weekly allowance reported is ₱1,870, indicating a moderate level of financial support for day-to-day expenses. These details provide a clear picture of the typical respondent in the study, which helps in understanding the context behind their responses and behaviors.

2. Short Soft-Skills

Table 2. Short Soft-Skills Earned by the Respondents

Short Soft Skills Earned (multiple response item, n=113)	**Frequency**	**Percent**
1 - Adaptability	23	20.4
2 - Time Management	22	19.5
3 – Teamwork	27	23.9
4 - Communication skills	37	32.7
5 – Emphatic	1	0.9
6 – Flexibility	3	2.7
7 - American Hospitality Academy (Hospitality Supervisor Certificate)	18	15.9
8 - Bartending	1	0.9
9 – CAHP	1	0.9
10 – CATP	1	0.9
11 - Leadership	12	10.6
12 - Critical Thinking	15	13.3
13 - Good Listening	2	1.8
14 – Creativity	4	3.5
15 - Work Ethic	1	0.9
16 - Cooking skills	3	2.7
17 - Decision making	5	4.4

Table 2 exhibits the short soft skills earned by the respondents. The top 5 skills earned by the respondents are communication skills (32.7%), teamwork (23.9%), adaptability (20.4%), time management (19.5%) and hospitality supervisor certificate from American Hospitality Academy (AHA) (15.9%).

According to these results, the respondents are making an effort to develop practical abilities, which are highly valued in both academic and professional settings. The findings imply that students place a high priority on learning soft skills that improve job readiness and productive workplace performance, particularly in the hotel and service-oriented sectors. The large number of students emphasizing communication, teamwork, and flexibility is evidence of increasing awareness of the value of these skills in customer service positions. Secondly, the seeking of

industry-recognized credentials such as the AHA supervisor certificate demonstrates a commitment towards acquiring a competitive advantage within the labor market, realigning their skillsets with industry standards, and improving their chances for employment after graduation (Baert et al., 2021; Elsawalhy & Elzek, 2023).

3. Micro-Badges

Table 3. Micro-Badges Earned by the Respondents

Micro Badges Earned (multiple response item; n = 113)	**Frequency**	**Percent**
1. Customer Service Management in Tourism and Hospitality (CSMTH)	46	40.7
2. Travel and Tourism Supervision (TTS)	45	39.8
3. Travel and Tourism Operations (TTO)	45	39.8
4. Certified Associate Tourism Professional (CATP)	31	27.4
5. Travel Geography (TG)	44	38.9
6. Destination Analysis (DA)	41	36.3
7. Travel and Tourism Management (TTM)	5	4.4
8. Certified Associate Hospitality Professional (CAHP)	32	28.3
9. American Hospitality Academy (AHA)	9	8.0
10. Food and Beverage Service Operation (FBSO)	9	8.0
11. Room Division Operations (RDO)	6	5.3
12. Room Division Supervision (RDS)	6	5.3

Table 3 presents the micro badges earned by the respondents. The top 5 micro badges earned by the respondents are Customer Service Management in Tourism and Hospitality (40.7%), Travel and Tourism Supervision (39.8%), Travel and Tourism Operations (39.8%), Travel Geography (38.9%), and Destination Analysis (36.3%).

These findings suggest that students are primarily interested in the main areas of the tourism and hospitality sector. The high figures on these particular badges reflect an intense interest and participation in building specialist knowledge and transferable skills about travel management, customer service, and destination planning.

The implication here is that students are developing specific competencies that directly align with their careers in tourism and hospitality. By achieving micro badges in such areas, they are strengthening their credentials and becoming more employable in the labor market. These badges not only authenticate their knowledge in particular topics but also prove that they are committed to ongoing education and professional development, which are highly appreciated by employers in the sector. This move indicates an aggressive strategy among students to ensure alignment of their skills with industry requirements and prepare themselves for future achievement (Giota & Bergh, 2021; Kao et al., 2022).

IV. SUPPORT SYSTEMS

Table 4. Support Systems for Facilitating Supplemental Skills and Micro Badges

Support Systems for Facilitating Supplemental Short Soft Skills Courses and Micro Badges (n=113)	**Wm**	**Verbal Description**
1. The supplemental short soft skill courses and micro badge programs are very accessible to us because of the support provided by our college.	3.64	Agree
2. The offered soft skill courses and micro badges are very relevant to our academic and career goals.	3.58	Agree
3. The quality of the content provided in these supplemental courses and badges is high.	3.55	Agree

4. The assistance given by the service providers is sufficient in guiding us through the soft skill courses and micro badge programs.	3.51	Agree
5. The technological infrastructure is enough (e.g., online platforms, tools) to assist us in acquiring short soft skills and micro badges.	3.50	Agree
6. We earned short soft skills and micro badges because of the convenient scheduling and preparations given by our service providers.	3.22	Moderately Agree
7. The short soft skills and micro badges attained by the students are well-recognized within the hospitality and tourism industry.	3.54	Agree
8. The support provided by our service providers for obtaining these skills and badges is sufficient.	3.52	Agree
9. The support systems are needed by us students since the soft skills and micro badges contribute to our personal growth and development.	3.58	Agree
10. I am very satisfied with the support systems provided to our service providers for attaining these skills and badges.	3.55	Agree
Overall Weighted Mean	**3.52**	**Agree**

Table 4 shows the support systems for facilitating supplemental short soft skills courses and micro badges as described by 113 respondents. It can be observed on the table that the respondents agreed that support systems are very good, with an overall weighted mean of 3.52. As described by the respondents, "The supplemental short soft skill courses and micro badge programs are very accessible to us because of the support provided by our college (Wm=3.64)", "The support systems are needed by us students since the soft skills and micro badges contribute to our personal growth and development (Wm=3.58)" and "The offered soft skill courses and micro badges are very relevant to our academic and career goals (Wm= 3.58)".

However, the least in terms of weighted mean is the item, "We earned short soft skills and micro badges because of the convenient scheduling and preparations given by our service providers (Wm=3.22)".

The results show that the support systems for supplemental short soft skills courses and micro badges are seen in a positive light by the respondents, implying that these systems are essential in the accessibility and perceived value of such programs. The participants confirmed that the WUP support hugely facilitates their participation in these initiatives and noted the significance of such systems in supporting personal development and career and academic goal congruence (Chamandy & Gaudreau, 2019). This indicates the power of well-supported soft skills programs to stimulate student development above technical expertise. Nevertheless, the comparatively lower rating of convenience in scheduling and preparations indicates that logistics continue to need enhancement. Meeting this would potentially add to participation and effectiveness, suggesting that although content and institutional support are sound, operational implementation has to be refined to maximize the advantages of such programs (McDonald et al., 2022).

V. STRATEGIES

Table 5. Strategies Provided by the Service Providers

Strategies Provided by Service Providers for Facilitating Supplemental Short Soft Skill Courses and Micro Badges (n=113)	**Wm**	**Verbal Description**
1. The strategies provided by our service providers clearly explain how to earn soft skills and micro badges.	3.25	Agree

2. I find the guidance from our service providers helpful in understanding the importance of earning soft skills and micro badges.	3.52	Agree
3. The resources shared by our service providers are adequate for achieving the required soft skills and micro badges.	3.52	Agree
4. Our service providers encourage active participation in activities that contribute to earning soft skills and micro badges.	3.53	Agree
5. The feedback I receive from our service providers helps me improve my progress toward earning soft skills and micro badges.	3.53	Agree
6. The strategies outlined by our service providers align well with my personal learning goals for soft skills development.	3.24	Moderately Agree
7. I feel motivated to pursue soft skills and micro badges due to the strategies introduced by our service providers.	3.22	Moderately Agree
8. Our service providers provide sufficient opportunities for me to apply the strategies in real-world or practical scenarios.	3.50	Agree
9. The instructions provided for earning soft skills and micro badges are easy to follow and implement.	3.58	Agree
10. I feel confident that the strategies shared by our service providers will help me successfully earn the desired soft skills and micro badges.	3.53	Agree
Overall Weighted Mean	**3.44**	**Agree**

Table 5 presents the strategies provided by service providers for facilitating supplemental short soft skill courses and micro badges as described by 113 respondents. It can be observed on the table that the respondents agreed that the strategies are very good, with an overall weighted mean of 3.44. As described by the respondents, "The instructions provided for earning soft skills and micro badges are easy to follow and implement (Wm=3.58"), "Our service providers encourage active participation in activities that contribute to earning soft skills and micro badges (Wm=3.53)" and "The feedback I receive from our service providers helps me improve my progress toward earning soft skills and micro badges (Wm=3.53)".

The least in terms of weighted mean is the item "I feel motivated to pursue soft skills and micro badges due to the strategies introduced by our service providers (Wm=3.22)".

The participants noted that instructions given carefully, active participation being encouraged, and feedback given constructively are some of the most effective methods in supporting their participation and progress. These factors seem to play a notable role in the effective application of the programs, emphasizing the need for effective communication and interactive assistance in skill development programs. The comparatively lower score for motivation implies that though the strategies work well to execute, they are perhaps not inspiring or engaging enough to maintain student drive. This suggests a requirement for service providers to incorporate more motivational factors, such as systems of recognition, tailored goals, or gamification, to increase learners' intrinsic motivation and long-term dedication to acquiring soft skills and micro badges (Ward et al., 2023).

VI. CONCLUSIONS

The following conclusions are derived from the results of the study:

1. The respondents, predominantly 22-year-old female BSHM students with a moderate weekly allowance, suggest a relatively mature and financially supported group.

2. The top 5 skills earned by the respondents are communication skills, teamwork, adaptability, time management and hospitality supervisor certificate from American Hospitality Academy (AHA).

3. The top 5 micro badges earned by the respondents are Customer Service Management in Tourism and Hospitality, Travel and Tourism Supervision, Travel and Tourism Operations, Travel Geography, and Destination Analysis.

4. The respondents find institutional support helpful for accessing soft skills and micro badge programs, but better scheduling and convenience are still needed to improve participation.

5. The strategies provided by service providers are helpful and clear, but they need to be more motivating to keep students fully engaged.

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Preparations and Inclinations of the CHTM'S National Skills Competition Winners

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Abstract *— This descriptive research entitled "Preparations and Inclinations of the College of Hospitality and Tourism Management's National Skills Competition Winners" investigated the specializations of 50 Wesleyan University Philippines' students, as well as their preparations and inclinations in joining the National Skills Competitions. The findings revealed that most students specialize in cooking and baking. Students feel most prepared for national skills competitions when they are well-informed and supported. Also, students are highly motivated to join national skills competitions because they see them as valuable opportunities for industry experience and professional growth. Lastly, the CHTM program should continue encouraging participation by promoting school pride and providing more chances for industry networking.*

Keywords *— Inclination, national culinary winners, motivation, preparation, tourism*

I. INTRODUCTION

Culinary and hospitality competitions have become prominent avenues for showcasing the skills, creativity, and discipline of future industry professionals. In the Philippines, national skills competitions serve as prestigious platforms where students in hospitality and tourism programs demonstrate not only technical expertise but also innovation and passion for their craft (Hari Wibisono et al., 2023; Toubes et al., 2023). These competitions cultivate excellence and provide invaluable experiences that shape students into competent, competitive, and industry-ready professionals.

At Wesleyan University-Philippines (WUP), the College of Hospitality and Tourism Management (CHTM) has consistently produced winners in various national skills competitions. These achievements highlight the college's commitment to developing well-rounded learners through hands-on training, practical application, and exposure to real-world industry standards. The CHTM program integrates theoretical knowledge with intensive practical exercises and mock competitions, ensuring that students are equipped not only with technical abilities but also with the confidence and adaptability essential in a competitive environment (Vo et al., 2022).

However, beyond the structured preparation and skill-building, the students' inclinations—such as their motivations, interests, and personal aspirations—play a vital role in their competitive success. Factors such as institutional support, mentorship, resource accessibility, and perceived career value influence how students prepare for and perform in these contests. Understanding these motivational tendencies is crucial in assessing the holistic development of CHTM students and the effectiveness of the university's training framework (Sieplinga et al., 2023).

This study, therefore, seeks to examine the preparations and inclinations of the CHTM's national skills competition winners. It aims to identify how

their training, experiences, and motivational factors contribute to their outstanding performance. By analyzing both the structural (preparation and support systems) and psychological (motivation and interest) components of their success, the research intends to provide meaningful insights that can further enhance the curriculum, training programs, and mentoring strategies of the CHTM department.

Despite the continued success of CHTM students in national competitions, it remains essential to understand the underlying preparations and motivational forces that drive their achievements. Thus, this study endeavors to explore the levels of preparation and inclinations of CHTM's national skills competition winners to determine how these aspects influence their competitive performance and professional growth (AIAP, 2019).

II. LITERATURE REVIEW

The National Skills Competition Context

National skills competitions are formal platforms that recognize excellence in technical-vocational education and training. In the Philippines, the Technical Education and Skills Development Authority (TESDA) organizes the Philippine National Skills Competition (PNSC) to identify and prepare outstanding competitors who can represent the country in regional and international contests. These competitions not only highlight individual achievement but also serve as mechanisms for aligning training programs with industry standards and global competencies (TESDA, 2024). The hospitality and tourism sector, in particular, benefits from these initiatives as they showcase the practical application of competencies essential for professional growth and employability.

Structured Preparation and Deliberate Practice

A major determinant of success in skill-based competitions is structured and purposeful preparation. The theory of deliberate practice developed by Ericsson (2019) emphasizes that expertise results from consistent, goal-oriented practice that focuses on improving specific aspects of performance through feedback and repetition. Macnamara et al. (2016) further demonstrated that deliberate practice, when coupled with reflective feedback and increasing task difficulty, leads to measurable improvements in skill mastery.

In hospitality and tourism education, deliberate practice can take the form of simulation exercises, skill sheets, and time-bound practice sessions aligned with competition rubrics. Research on vocational education indicates that structured practice with immediate feedback significantly enhances competence and confidence among trainees (Macnamara et al., 2016). Thus, understanding the specific training routines and feedback mechanisms of CHTM competitors can provide insight into how preparation translates into exceptional performance.

Mentoring, Coaching, and Institutional Support Systems

Beyond individual effort, mentoring and coaching play crucial roles in shaping competitors' success. Mentorship provides both technical and psychosocial support, guiding students through complex skill requirements while fostering motivation and professional identity. A systematic review of mentorship programs revealed that effective mentoring relationships contribute significantly to skill development, confidence, and long-term career commitment (Systematic Review of Mentorship Programmes, 2025).

Similarly, coach education research highlights that mentors who offer structured feedback, reflective guidance, and emotional support create environments conducive to high performance (Vink, 2023). Institutional support—including access to modern equipment, training venues, and funding—also enhances preparation quality. TESDA (2024) underscored that institutions providing comprehensive support systems produce competitors who are better equipped to meet national and international standards.

For CHTM students, mentorship and institutional backing are particularly vital, as hospitality competitions often require both technical precision and service-oriented behavior. Understanding these support mechanisms provides a holistic view of preparation that extends beyond individual ability.

Motivation, Self-Efficacy, and Psychological Inclination

Psychological factors such as motivation, self-efficacy, and interest are powerful predictors of performance.

Drawing from Self-Determination Theory (SDT), motivation exists along a continuum from intrinsic (driven by enjoyment and mastery) to extrinsic (driven by rewards or recognition). In hospitality education, intrinsic motivation is associated with deeper learning engagement and resilience during challenges (Cesário et al., 2022; Guo et al., 2023).

Guo et al. (2023) found that students who perceived higher self-efficacy—confidence in their ability to perform tasks successfully—showed stronger persistence and higher achievement. Similarly, Cesário et al. (2022) emphasized that students' interest and passion for hospitality-related skills significantly influence their sustained participation and excellence in competitive environments.

In the context of skills competitions, winners are often distinguished not only by their competence but also by their intrinsic drive to excel. This suggests that understanding the motivational profiles and psychological inclinations of CHTM competitors can reveal how internal dispositions interact with structured preparation to produce outstanding results.

Career Aspirations, Recognition, and Long-Term Outcomes

Winning national competitions extends beyond immediate recognition; it shapes future career trajectories. Literature on hospitality education suggests that awards and achievements enhance professional identity, increase employability, and motivate continued engagement in the industry (Guo et al., 2023). TESDA (2024) similarly reported that national competition winners often secure leadership roles in hospitality institutions and become ambassadors for technical education.

Participation in such competitions strengthens students' career orientation and sense of purpose, aligning with findings that early recognition fosters lifelong professional motivation (Systematic Review of Mentorship Programmes, 2025). Understanding post-competition outcomes of CHTM winners therefore offers insight into how recognition and achievement influence sustained engagement in hospitality careers.

III. METHODOLOGY

This research utilized a descriptive quantitative research design. According to Sirisilla (2023), "scientists and researchers use descriptive research design as a powerful tool to gather information about a particular group or phenomenon". Fifty (50) Bachelor of Science in Hotel and Restaurant Management were chosen purposively (Subia, 2018) as respondents of this study. According to Campbell (2020), "Purposive sampling strategies move away from any random form of sampling and are strategies to make sure that specific kinds of cases of those that could be included are part of the final sample in the research study". It uses certain criteria to include the qualified respondents. The criteria for choosing the respondents are the following: 1. National culinary winner; 2. Representative of Wesleyan University Philippines; and 3. Willing to participate in this research.

The instrument used in this study was a researcher-made instrument that was content validated by five (5) experts, while the reliability was established using Cronbach's alpha with a reliability value of 0.912. The study covers one year only.

IV. RESULTS AND DISCUSSION

1. Specialization

Table 1. Specialization of the Hospitality Management & Tourism Managements Students

Specialization	Frequency	Percent
1 - Culinary and Kitchen Service	14	28.0
2 - Cake Decorating	9	18.0
3 - Confectionery Arts	6	12.0
4 - Restaurant Service	2	4.0
5 - Food Photography	1	2.0
6 - Classic Fusion	1	2.0
7 - Baking and Pastry Arts	5	10.0
8 - Fruit carving	1	2.0
9 - Coffee barista	2	4.0
10 - Hot Dishes	1	2.0
11 - Asian Cuisine	1	2.0

12 - Western Cuisine	1	2.0
13 - Food Styling	1	2.0
14 - Regional Cuisine	1	2.0
15 - Bartending	4	8.0
Total	**50**	100.0

Table 1 shows that most of the CHTM national skills competition winners specialized in Culinary and Kitchen Service (28%), followed by Cake Decorating (18%) and Confectionery Arts (12%). This indicates that culinary-focused training remains the college's strongest area, where students demonstrate exceptional technical skills, creativity, and discipline. According to Hari Wibisono et al. (2023), culinary competitions serve as valuable platforms for enhancing students' professional competence and creativity by simulating real-world kitchen challenges. Likewise, Toubes, Araújo-Vila, and Fraiz-Brea (2023) emphasize that participation in such competitions cultivates innovation and adaptability—key attributes in the hospitality industry.

The relatively lower participation in Restaurant Service, Bartending, and Coffee Barista specializations suggests that while these areas are integral to the hospitality program, they receive less focus in terms of competition preparation or institutional prioritization. Vo et al. (2022) highlight that structured practical training and mentorship are critical in motivating students to participate in diverse skill-based contests. Hence, broadening institutional support and resources in service-oriented and beverage categories could encourage greater involvement and achievement in these areas.

Overall, the results affirm that CHTM students are more inclined toward culinary artistry and food production, reflecting the university's strong culinary training foundation. This supports the view of Sieplinga et al. (2023) that both skill preparedness and motivational tendencies significantly influence student performance in competitions. Thus, continuous enhancement of both technical preparation and motivational support systems will sustain and expand the CHTM's success in future national skills competitions.

2. Preparation

Table 2. Preparation for National Skills Competition

Preparation for National Competition	**Wm**	**Verbal Description**
1. I feel confident in applying the skills I have learned during my academic training to competitive settings.	3.76	Agree
2. The WUP provides sufficient resources (e.g., equipment, ingredients) for effective competition preparation	3.56	Agree
3. The training sessions conducted by my mentors adequately prepared me for the challenges of national skills competitions.	3.73	Agree
4. I receive constructive feedback from mentors that helps improve my performance in practices.	3.86	Agree
5. Our curriculum includes sufficient practical experiences to prepare me for skills competitions.	3.84	Agree
6. I am well-informed about the rules and guidelines of national skills competitions through our college-organized briefings.	3.88	Agree
7. My teamwork and collaboration skills have been enhanced through group activities related to skills competition preparation.	3.84	Agree
8. The WUP provides adequate opportunities for mock competitions to simulate real competitive environments.	3.78	Agree
9. I feel interested because of the support provided by the CHTM faculty and my peers in	3.86	Agree

preparing for national skills competitions.		
10. Our College's emphasis on innovation and creativity has improved my ability to present unique dishes during competitions.	3.82	Agree
Overall Weighted Mean	3.79	Agree

Table 2 shows the preparation of the respondents in their national skills competition. The top 3 in terms of weighted mean are the items "I am well-informed about the rules and guidelines of national skills competitions through our college-organized briefings (Wm=3.88), "I receive constructive feedback from mentors that helps improve my performance in practices (Wm=3.86)", and "I feel interested because of the support provided by CHTM faculty and my peers in preparing for national skills competitions (Wm=3.86).

The findings show that the students feel most prepared in areas where they are well-informed, supported, and guided. Many said they clearly understood the rules of the competition through college briefings. They also felt that the feedback from their mentors helped them improve their cooking skills. In addition, students shared that they were more interested and motivated because of the support from their teachers and classmates.

These results show that proper guidance and a supportive environment help students feel more confident in competitions. The CHTM program should continue giving clear briefings, helpful feedback, and strong encouragement. This kind of support not only builds skills but also boosts motivation, which can lead to better performance in national skills contests (James & Mathew, 2023).

3. Motivation

Table 3. Motivation/Inclination for National Skills Competition

Motivation/Inclination for National Skills Competition	**Wm**	**Verbal Description**
1. I am highly interested in participating in and winning every national skills competition.	3.84	Agree
2. I believe that participating in skills competitions enhanced my career opportunities in the hospitality and tourism industry.	3.80	Agree
3. I am motivated to improve my skills to meet the standards of national competitions.	3.84	Agree
4. I enjoy the challenge of competing against other students from different institutions in skills events.	3.86	Agree
5. I see national skills competitions as an opportunity to showcase my creativity and innovation in cooking.	3.84	Agree
6. I feel a sense of pride and responsibility representing Wesleyan University Philippines in skills competitions.	3.88	Agree
7. I am willing to dedicate extra time and effort to prepare for national skills competitions.	3.74	Agree
8.I am inspired by the success stories of previous participants from our university in national skills competitions.	3.84	Agree
9. I believe that participating in national skills competitions helped me gain valuable experience and exposure in the industry.	3.90	Agree
10. I always feel excited about the possibility of networking with other industry professionals	3.88	Agree

during national skills competitions.		
Overall Weighted Mean	3.84	Agree

Table 3 presents the motivation/inclination of the respondents for the national skills competition. Overall, the respondents are motivated and inclined in the competition, as shown in the overall weighted mean of 3.84. The top 3 highest items in terms of weighted mean are items number 9 "I believe that participating in national skills competitions helped me gain valuable experience and exposure in the industry (Wm=3.90)", "I always feel excited about the possibility of networking with other industry professionals during national skills competitions (Wm=3.88)" and "I feel a sense of pride and responsibility representing Wesleyan University Philippines in skills competitions (Wm=3.88).

The finding shows that students are highly motivated and inclined to join national skills competitions. They believe that these events give them valuable experience and exposure in the hospitality industry. Many also feel excited about the chance to meet and connect with professionals during the competitions. In addition, students take pride and feel a strong sense of responsibility when representing Wesleyan University-Philippines in these events.

These findings suggest that national competitions do more than just test cooking skills. They also help students grow professionally and personally. The CHTM program can use this motivation to further encourage student participation by highlighting the real-world benefits of joining competitions. Promoting pride in representing the university and offering more opportunities for industry networking can strengthen student engagement and enhance their career readiness (Dodd, Hanson & Hooley, 2022).

V. CONCLUSIONS AND RECOMMENDATIONS

The following are conclusions derived from the findings of the study:

1. Most students specialize in cooking and baking, so WUP's CHTM program should strengthen training in these areas while also promoting less chosen fields like bartending.

2. Students feel most prepared for national culinary competitions when they are well-informed and supported, so the CHTM program should continue providing clear briefings and strong mentorship to build both skills and confidence.

3. Students are highly motivated to join national culinary competitions because they see them as valuable opportunities for industry experience and professional growth.

4. The CHTM program should continue encouraging participation by promoting school pride and providing more chances for industry networking.

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