Jakarta, 07th of April 2024
No. : 009- ICASTE/EXT/UNTAR/IV/2024

ABSTRACT ACCEPTANCE NOTIFICATION

Paper ID	:	**009-ICASTE**
Title	:	**Analysis Of The Influence Of Light Intensity And Temperature On Work Speed. Case Study of 4 Color Pen Assembly**
Author	:	**I Wayan Sukania, Lamto Widodo, Rymartin Jonsmith Djaha, Michael Hidayat**

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Judul Kegiatan/Aktifitas	:	ICASTE 2024
Tingkat	:	INTERNASIONAL
Peran	:	Peserta
Periode/Tahun/Tanggal	:	25 April 2024
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ANALYSIS OF THE INFLUENCE OF LIGHT INTENSITY AND TEMPERATURE ON WORK SPEED. CASE STUDY OF 4 COLOR PEN ASSEMBLY.

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Enter : dd-mm-yyyy, revision: dd-mm-yyyy, accepted for publication : dd-mm-yyyy

ABSTRACT

Ergonomics plays an important role in achieving work comfort. By using ergonomic principles, a work environment and workstation can be designed in such a way that suits human characteristics and limitations so that humans can work efficiently, effectively, productively, safely and comfortably. The right work environment factors according to the characteristics of the people working in it ensure optimal productivity and quality of work results. One of the work environment factors is workspace temperature and lighting. Likewise, the more thorough the work that must be done, the brighter the lighting required. Research to find the characteristics of the working speed of the 4-color pen assembly process is associated with variations in working room temperature and variations in light brightness in the workplace. The research took respondents from Untar industrial engineering students. Based on theoretical studies, research results and similar research studies, data was obtained that work environmental factors, namely temperature and lighting, influence the speed of assembling 4-color pens. The speed of assembling a 4 color pen can be done the fastest under normal temperature conditions and normal lighting. Extreme conditions, namely cold temperatures, hot temperatures, too bright and dim lighting result in longer assembly speeds. The recommended workspace climate is a temperature of 240C and normal lighting of 200 – 300 lux.

Keywords: *temperature, bright light, working speed.*

1. PREFACE

Every player in industrial activities, both manufacturing and service industries, all want optimal productivity, efficiency and quality of results. The field of industrial engineering as studied in the Untar industrial engineering study program always synergizes every lecture material in it so that efficient, effective and quality output is produced. Meanwhile, the work environment and stations where activities are carried out are designed in such a way as to provide safety and comfort in working.

Ergonomics and work system design are one of the main study materials that must be understood well. Ergonomics comes from Greek which consists of two words, namely "ergon" which means work and "nomos" which means rule or law. In short, the definition of ergonomics is a rule or norm in a work system [1]. Ergonomics is a science which in its application seeks to harmonize work and the environment for people as much as possible through optimal use of human factors, which includes reciprocal harmonization of work and labor for work efficiency and comfort [2]. Ergonomics is the science, art and application of technology to harmonize or balance all the facilities used for activity and rest with human abilities and limitations, both physical and mental, so that the overall quality of life becomes better [3]. Ergonomics is a scientific field about how to harmonize humans with their work and work environment in order to create comfort, safety and prevent injuries and health problems with the aim of increasing work productivity and a better

quality of human life. Thus, the application of ergonomic principles is absolute for increasing safety, comfort, productivity and quality of work results.

Environmental factors for work include temperature, lighting, air quality, color, noise, vibration, etc. Based on the research results, all factors influence the performance of workers in it. The temperature factor is an important factor for work comfort. Finding an office temperature that is suitable for all employees is not easy. The right office temperature will increase satisfaction, productivity and collaboration among employees. Meanwhile, failure to find the right office temperature for all employees will not only reduce work productivity, but can also make workers sluggish, fat, get sick easily, and affect company finances [4]. A work environment with high temperatures is one of the most important factors that has an impact on work safety. There are several high temperature work environments in industrial and construction activities in Indonesia. Working in a hot environment with a heavy workload is not only very dangerous for workers' health but will also result in decreased levels of concentration in carrying out work which can cause accidents [5].

Table 1 presents the standards for work space lighting levels in accordance with the Decree of the Indonesian Minister of Health No. 1405/MENKES/SK/XI/2002, concerning Minister of Labor Regulation no. 7 of 1964 concerning Health, Cleanliness and Information Requirements in the Workplace [6].

Table 1. Workspace lighting standards in accordance with Republic of Indonesia Minister of Health Decree No. 1405/MENKES/SK/XI/2002 [6].

Type of Work	***Example***	***Lighting Level (Lux)***
General	Interchange or warehouse space	80 - 170
Ordinary Throughness	Packing, assembly, lathe, milling, painting, drilling	200 - 300
Work Carefully	Reading, writing, assembly of precision tools	500 - 700
Very Thorough Work	Engineering drawing, electronic equipment test, inspection	1000 - 2000

So the level of lighting in the workplace is adjusted to the type of work carried out in the work space. Other research shows that productivity is influenced by several things, one of which is the influence of the work environment and work climate [7]. In general, 2 work environment factors, namely work space temperature and lighting, affect the performance of workers who work there. Figure 1 presents lighting at an industrial workstation. Therefore, it is very necessary to know and understand the characteristics of temperature and lighting factors on work speed in various industrial activities. Carrivick et al. [28] explained that working anywhere cannot be separated from workload, because in the process of work activities requires simultaneous muscular and mental work which is shown through fatigue which is characterized by changes in pulse frequency.

A fit condition is characterized by a low level of workload during workplace activities. Work load can be reduced or even eliminated if people carrying out activities can still be in their natural position [30]. For this reason, by knowing data on the characteristics of temperature and lighting factors on work speed, it will really help business owners to provide the right work station so that productive conditions are achieved. , effective and convenient. This research focuses on a 4 color pen assembly job. The results obtained from the research results are the best temperature and lighting levels which are characterized by the fastest completion of work.

Ergonomics

Etiomologically, ergonomics comes from the Greek words ergon which means work and nomo which means rule or law. The definition of ergonomics is the rules about how to do work, including work attitudes. The definition of ergonomics as a systematic branch of science to utilize information about human characteristics, abilities and limitations in designing a good work system to achieve the desired goals through effective, efficient, safe and comfortable work [8]. Ergonomics is the science, art and application of technology to harmonize all the facilities used both in activities and in rest based on human abilities and limitations, both physical and mental, so that the overall quality of life becomes better [9]. In the world of work, ergonomics plays a big role and all areas of work require ergonomics. Ergonomics applied in the world of work makes workers feel comfortable when doing their work. Having this feeling of comfort will be beneficial to the expected work productivity and can increase it [10]. The IEA (International Ergonomics Association) defines Ergonomics as a scientific discipline concerned with understanding the interactions between humans and other elements of systems, and a profession that applies theoretical principles, data and methods to design to optimize the well-being and overall performance of human systems. Ergonomics practitioners contribute to the planning, design, and evaluation of tasks, jobs, products, organizations, environments, and systems in order to make them compatible with human needs, abilities, and limitations [11].

In general, the application of ergonomics aims to improve physical and mental well-being through preventing work-related injuries and illnesses, reducing physical and mental workload, seeking promotions and job satisfaction. The next goal is to improve social welfare through improving the quality of social contacts, managing and coordinating work effectively and increasing social security both during the productive age period and after being unproductive. Meanwhile, the third goal is to create a rational balance between various aspects, namely technical, economic, anthropological and cultural aspects of every work carried out so as to create a high quality of work and quality of life [12].

Work Enviroment Factors

A person's performance in carrying out their work often depends on the physical environment in which the work is carried out. A physical environment that is not well designed can affect the health and safety of workers. The work environment consists of elements, such as setting, social features, and physical conditions that can influence an employee's sense of well-being, workplace relationships, collaboration, efficiency, and health. The work environment is a collection of tools around employees, such as tables, chairs, laptops, temperature, and so on which can affect employee performance. The work environment can be said to be good and conducive if employee performance and productivity increases. On the other hand, the work environment can be said to be bad if employee performance and productivity decreases [13].

Furthermore, several factors that influence the physical work environment include color, cleanliness, air circulation, lighting and security. [14]. Meanwhile, the factors that influence the formation of a work environment include temperature, humidity, air circulation, lighting, noise, mechanical vibrations and security [15]. Elements of the physical work environment, namely lighting, air circulation, color, cleanliness, security.

Workinng Room Temperature

Based on the Regulation of the Minister of Public Works Number 29/PRT/M/2006, several criteria for building comfort are required, including movement comfort, thermal comfort, visual comfort and audial comfort. The temperature factor as an indicator of thermal comfort is important. The human body always tries to maintain a normal state with a perfect body system so that it can adapt

to changes that occur outside the body. Human productivity will reach the highest level at temperatures of 24°C-27°C [16]. If the room temperature is very low, the skin surface temperature will decrease and conversely, if the indoor temperature is high, it will also increase.

The effect on work activities is that temperatures that are too cold will reduce enthusiasm for work and temperatures that are too hot can make you tired at work and tend to make lots of mistakes. Increasing human body temperature causes behavioral responses such as decreased physical activity, removing clothing, moving away from heat sources, and cognitive responses, such as reduced concentration and increased errors [29]. Ministerial Regulation Number 29 of 2005 concerning Guidelines for Technical Requirements for Buildings regulates room temperature [17].

Lighting

Lighting in the workplace is an important factor in a person's work results. Lighting is used as an ergonomic indicator of space with the consideration that the comfort of indoor activities is influenced by the light that enters the room. Not all rooms need the same amount of light. The need for light depends on the activities carried out in the room [18]. Lighting needs, apart from being influenced by activities carried out indoors, are also influenced by the age of the user. It can be seen that each person's light needs vary depending on age, the size of the visible object, and the level of accuracy/difficulty of the work carried out in the room. It is also known that a 60 year old person needs 15x higher levels of light than a 10 year old child. So even though the activity being carried out is the same, if humans act as the perpetrators of the activity, it is different, the level of lighting required is also different [18].

According to laboratory studies, exposure to light at cool color temperatures improves mood and alertness, attention, and memory. However, its overall effects are not well understood [31]. Light is basically electromagnetic waves that can be seen by the eye [19]. One approach that can be taken to find out whether the lighting conditions in the workplace meet expectations is to measure the illuminance from a light source. Illumination is a measure of the amount of light falling on a surface or workpiece. The amount of illumination depends on how far it is from the light source to the workpiece or work being done. The unit for the amount of light is lux (lx) and is measured using a light meter (illumincace/lightmeter) [1].

There are 2 types of lighting used, namely natural lighting and artificial lighting. Natural lighting is a source of lighting that comes from sunlight. This lighting source is considered less effective than using artificial lighting sources. This is because the sun cannot provide a constant light intensity. Natural lighting requires large windows, glass walls, walls with lots of holes and can be expected to be expensive. To get sufficient natural lighting in a room, windows are needed at 15 – 20% of the floor area [19].

Meanwhile, artificial lighting is lighting produced by light sources other than natural light. If natural lighting is inadequate or the position of the room is such that natural lighting is difficult to achieve, artificial lighting can be used. The lighting standards according to Indonesian National Standard 03-6197-2000 concerning Energy Conservation in lighting systems contain lighting standards in various places such as hospitals, offices, educational institutions, work areas, etc. [20]. Minister of Manpower Regulation (Permenaker) number 5 of 2018 is the main regulation that regulates aspects of the work environment and industrial hygiene [21]. Figure 1 shows the lighting at a workstation [22].

Figure 1. Lighting at Industrial Workstations [22]

2. RESEARCH METHOD

This research is quantitative research carried out in the work systems and ergonomics design laboratory. The measuring instrument used is 4 in 1 to measure room air temperature and a light measuring instrument. as in Figure 2. Meanwhile, to measure assembly work speed using applications available on mobile phones, Figure 3. The research stages are presented in Figure 6.

Figure 2. 4 In 1 Measuring Instrument.

Figure 3. Stopwatch Application.

The materials used in this research were 4 color pens. The 4-color pen will be disassembled and reassembled under several different combinations of temperature and lighting conditions to determine the assembly time. Assembly activities are carried out in the climate room, Figure 5. Meanwhile, the 4 color pen is presented in Figure 4.

Figure 4. 4 Color Pens

Figure 5. Climate Room

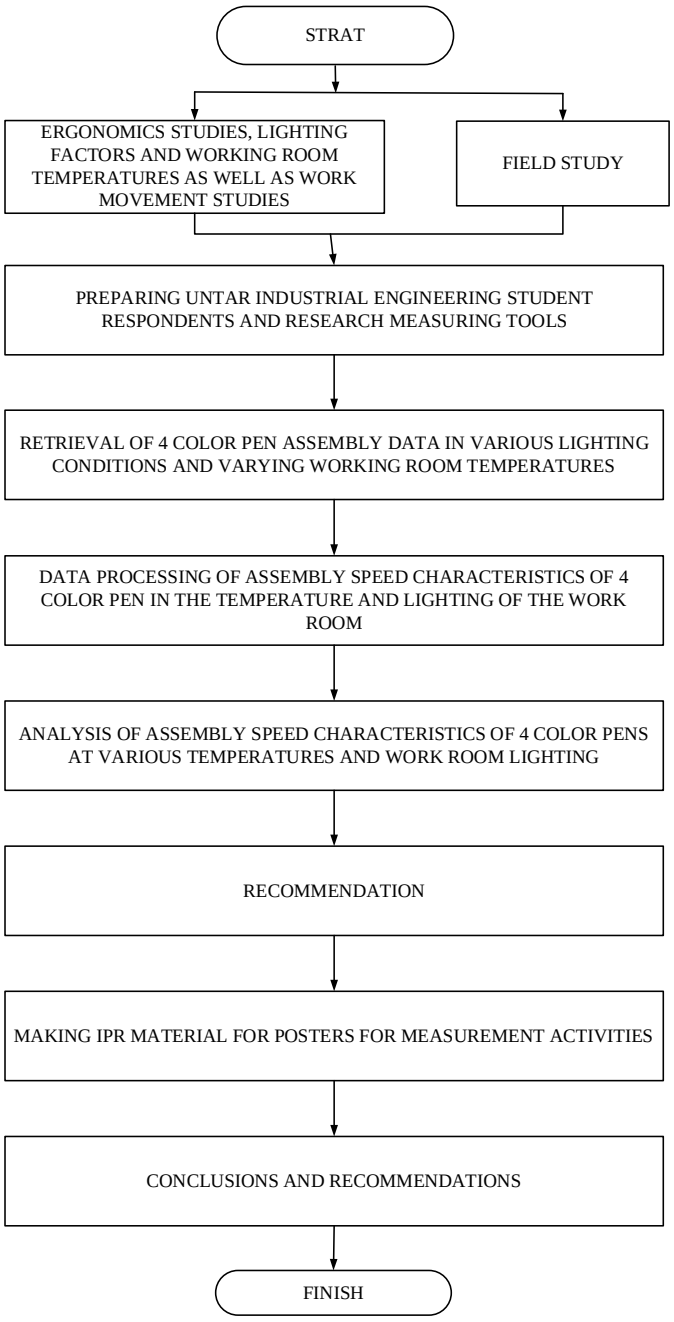

Figure 5 Research Flow Diagram.

Data dan Analisis.

This research in the field of ergonomics involved respondents from Tarumanagara University Industrial Engineering students. For ease of data collection, students were grouped into 11 groups. The following is an example of measurement data presented in Table 1. Meanwhile, a summary of the results of data processing using statistical software is presented in Table 2 below. The data is processed to obtain the characteristics of the measurement data, including average, standard deviation, data adequacy and data normality. Some documentation of research activities is presented in Figure 6, Figure 7 and Figure 8.

Table 1. Data on Assembly Time for 4 Color Pens in Very Bright and Cold Conditions

Intensity Light (Lux)	***Temperature (^{O}C)***	***Practice Time (Seconds)***			
		Practitioner 1	***Practitioner 2***	***Practitioner 3***	***Practitioner 4***
177	21,1	56	58	60	91
177	21,1	51	53	55	84
177	21,1	69	70	64	73
177	21,1	61	80	78	89
177	21,1	74	63	83	85
177	21,1	52	76	72	81
177	21,1	77	71	66	79
177	21,1	68	65	56	75
177	21,1	59	87	67	86
177	21,1	62	54	57	82

Figure 6. 4 Color Pen Assembly Activity Condition 4 Dark - Hot

Figure 7. 4 Color Pen Assembly Activities Condition 6 Bright-Hot

Figure 8. 4 Color Pen Assembly Activity Condition 5 Very Bright - Hot

Table 2. Statistical Summary of Measurement Data

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Kondisi Sangat Terang dan Dingin	180	52.00	47.00	99.00	73.8778	12.79388	163.683	.356	.181	-.889	.360
Kondisi Sangat Terang dan Normal	180	65.00	30.00	95.00	69.4889	12.90597	166.564	.199	.181	-.426	.360
Kondisi Sangat Terang dan Panas	180	74.00	33.00	107.00	78.9833	15.24125	232.296	-.315	.181	-.565	.360
Kondisi Terang dan Dingin	180	60.00	39.00	99.00	72.4889	13.41245	179.894	.418	.181	-.635	.360
Kondisi Terang dan Normal	180	64.00	31.00	95.00	61.1722	14.71435	216.512	.706	.181	-.240	.360
Kondisi Terang dan Panas	180	45.00	49.00	94.00	71.2167	11.15021	124.327	.445	.181	-.946	.360
Kondisi Gelap dan Dingin	180	82.00	56.00	138.00	94.2556	19.09170	364.493	.091	.181	-.632	.360
Kondisi Gelap dan Normal	180	75.0	50.0	125.0	88.061	17.7355	314.549	-.189	.181	-.722	.360
Kondisi Gelap dan Panas	180	59.00	61.00	120.00	87.4778	12.26407	150.407	.390	.181	-.366	.360
Valid N (listwise)	180										

Several images describing the normality of the data are presented in Figure 9 below.

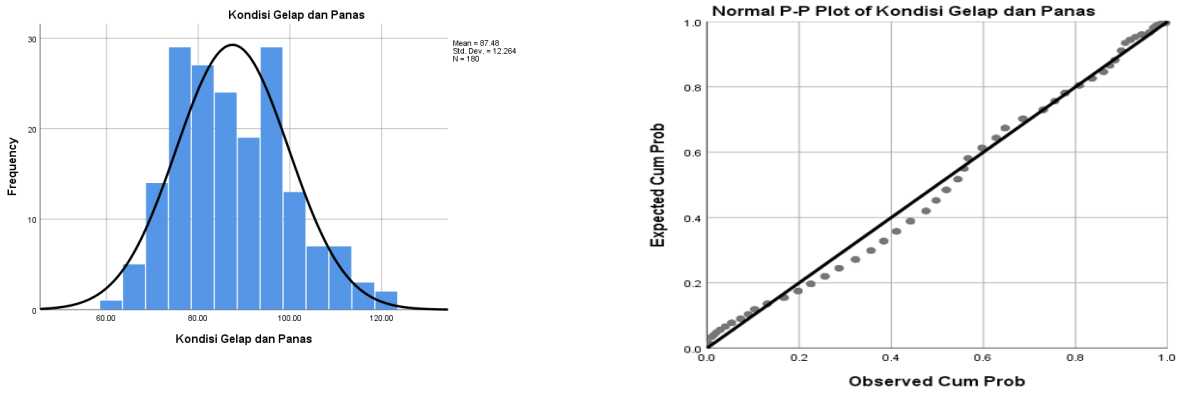

Figure 9. Normal Curve and Normality Test
Data on Dark Conditions and Hot Temperatures

3. RESULT AND DISCUSSION

Humans in carrying out their activities always use work facilities and work stations that are in certain work environment conditions. If the facilities and work environment are supportive, then activities can be carried out well and smoothly. On the other hand, if the work is carried out using facilities and a work environment that is not supportive, the work will take longer to complete and the quality of the work results may decrease. Research shows that the work environment has a positive effect on work productivity [23]. Therefore, in creating a work station, an ergonomic work station is needed to harmonize work and the environment by taking into account human strengths and limitations so as to form an efficient, productive and ergonomic work system [2]. Work environmental factors in which humans carry out activities consist of temperature, lighting, air quality, color, noise, vibration, etc. Work environmental factors in the form of temperature and lighting influence worker performance in the work system [24].

One of the work environment factors is the temperature factor. Workspace temperature is very important for work comfort. The temperature of the work space also determines the work speed of the operator in carrying out his activities. Based on the results of data processing on the activity of assembling 4-color pens, the results showed that the speed of assembling pens with the fastest time occurred in working environment conditions with bright lighting and normal working temperatures. On the other hand, the speed of assembling the pen is slowest when the work environment is low light (dark) but the air temperature is cold. The fastest assembly time was 61.17 seconds and the longest assembly time was 94.26 seconds. Based on research data on pen assembly, it was found that there was a positive correlation between pen assembly speed and working room temperature. The highest assembly speed was obtained in a work space with normal temperatures, both in dark, normal and very bright lighting conditions. The results of this study are in line with the opinion that cold temperatures reduce efficiency with complaints of stiffness or lack of muscle coordination. Hot temperatures especially result in decreased mental work performance. The decrease is very great after 32 °C. Hot temperatures reduce agility, prolong reaction time and decision-making time, disrupt the accuracy of brain work, disrupt sensory and motor nerve coordination [25]. Another study involving assembly work also found workspace temperature to influence assembly speed [26]. Meanwhile, failure to find the right office temperature for all employees will not only reduce work productivity, but can also make workers sluggish, fat, get sick easily, and affect company finances [4]. Working environment temperature is also related to work safety. Working in a hot environment with a heavy workload is not only very dangerous for workers' health but will also result in decreased levels of concentration in carrying out work which can cause accidents [5]. Therefore, the working environment temperature needs to be set in such a way that it provides comfort for workers at the work station. In simple terms, the comfortable temperature is set at 240C [17].

The lighting factor in the workplace is also an important factor that determines performance, especially in manufacturing activities and assembling products which are carried out manually. Lighting is used as an ergonomic indicator of space with the consideration that the comfort of indoor activities is influenced by the light that enters the room. Indeed, not all rooms need the same amount of light. The need for light depends on the activities carried out in the room [18]. In this study, lighting variables were divided into 3 types, namely slightly dark, normal and very bright. Lighting conditions at the research site are regulated by adjusting the power of the lights used during the research. The lighting value is measured using a light meter (illumincace/lightmeter) [1]. The results of research data processing on assembling 4-color pens show that the speed of assembling pens is positively correlated with the lighting at the research site. At normal temperature, the fastest assembly speed, namely 61.17 seconds, was obtained when

the work room was with normal lighting. Lighting conditions that are too bright result in a slower assembly speed of 69.49 seconds. The slowest assembly speed, namely 88.06 seconds, was obtained when the working space had less lighting. This is in line with similar research which found that poor lighting causes eye fatigue which in turn affects work speed. Insufficient lighting intensity makes workers' eyes work harder to see an object, which can trigger eye fatigue in workers [27]. Other research also finds that it is important to pay attention to the age of workers. It can be seen that each person's light needs vary depending on age, the size of the visible object, and the level of accuracy/difficulty of the work carried out in the room. It is also known that a 60 year old person needs 15x higher levels of light than a 10 year old child. So even though the activity being carried out is the same, if humans act as the perpetrators of the activity, it is different, the level of lighting required is also different [18]. In simple terms, for work spaces for packaging, assembly, lathes, milling, painting, drilling, the recommended lighting is 200 – 300 lux [6].

4. CONCLUSIONS AND RECOMENDATION

Based on theoretical studies, research results and similar research studies, the conclusions that can be drawn from research in the field of ergonomics are:

a. Work environment factors, namely temperature and lighting, influence the speed of assembling 4-color pens.
b. The speed of assembling a 4 color pen can be done the fastest under normal temperature conditions and normal lighting. Extreme conditions, namely cold temperatures, hot temperatures, too bright and dim lighting result in longer assembly speeds.
c. Based on the results of research and theoretical studies, optimal conditions were obtained, namely an ergonomic temperature of 240C and normal lighting of 200 – 300 lux.

Acknowlegdement

The research team would like to thank the industrial engineering study program for providing the tools and space to carry out measurement activities. The research team would also like to thank the industrial engineering students who were willing and participated in this activity.

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In Recognition of the Contribution as Authors of the Paper Entitled

SYSTEMATIC LITERATURE REVIEW INNOVATION MODEL AS A MEDIATING AND MODERATING VARIABLE IN MSMEs PERFORMANCE

Presented at the

International Conference on Economics, Business, Social, and Humanities

FTU, Hanoi, Vietnam, April 25th, 2024

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