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Measurement of Sound Pressure Level and Noise Flow of a Split-Type Air-Conditioner Outdoor Unit

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Abstract: The study was conducted in accordance with ISO 3741-2 and Department of Environment standards, using a TES-1353-H sound level meter. Three modes of operation were studied: fan, cool, and turbo. The unit was tested at different operating conditions, including fan speeds, temperature settings, and outdoor temperatures. The sound pressure level was measured around the unit, including the front, back, and sides. The study results showed that the noise level generated by the unit in the cool mode met the standards the Department of Environment set, with an average sound pressure level of 61.31 dB. However, the noise level generated by the unit in the turbo mode exceeded the maximum limit of 68 dB, with an average sound pressure level of 69.41 dB. The noise level generated by the unit in the fan mode also exceeded the maximum limit of 68 dB, with an average sound pressure level of 71.16 dB. The findings of this research can be used to improve the design and operation of outdoor units to reduce noise pollution and improve overall customer satisfaction. The study suggests that the noise level generated by the unit in the cool mode is within the acceptable range and that the unit can be operated in this mode without causing a disturbance to the surrounding environment. However, the unit should not be operated in the turbo or fan modes, as the noise levels generated in these modes exceed the maximum limit the Department of Environment sets.

Keywords: Sound pressure level, noise pollution, outdoor unit.

1. Introduction

The use of air conditioners in households in Malaysia has become increasingly prevalent in recent years due to the hot and humid climate. As temperatures continue to rise and heat waves become more frequent, the demand for air conditioners has been growing rapidly [1]. However, the widespread use of air conditioners in households in Malaysia is not without its challenges. One of the major concerns is the noise generated by the outdoor units of these air conditioners [2]. This noise, often described as a low humming or a loud, disruptive noise, can be heard inside and outside the home, causing annoyance and disruption to daily life. The problem of noise from the outdoor units of air conditioners is becoming more prevalent in Malaysia, as more and more households are installing air conditioners to cope with the heat and humidity [3]. This issue can be particularly severe for households close to one another, such as apartment buildings and townhomes, where the noise can easily carry to neighbouring units.

Furthermore, in Malaysia, many residential areas are located near commercial and industrial areas, where the noise from the outdoor unit can be particularly disruptive. The outdoor unit air conditioner noise can significantly impact the quality of life for households with air conditioners [4]. It can disrupt sleep, cause annoyance, and negatively affect mental and physical well-being. The noise can also be a problem for households living close to one another, such as in apartment buildings or townhomes, where the noise can easily carry to neighbouring units.

Noise pollution can be a source of complaints, lead to conflicts between neighbours, and affect the local wildlife and environment [5]. The problem of noise generated by the outdoor units of air conditioners is a significant concern that demands attention. It can harm the quality of life of households with air conditioners and negatively affect the surrounding community [6]. This study aims to address the increasing noise problem caused by the outdoor units of air conditioners in households in Malaysia and the potential impacts on individuals and communities.

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Furthermore, for this study, some data will be collected on noise problems in air conditioner outdoor units and will use a combination of observational surveys and sound-level meter measurements. After that, the data will be analysed using statistical techniques to identify patterns and trends. To compare data, we will compare the results with recommended noise levels for outdoor units and previous studies on the same topic and authorities' regulations. This study will provide insight into the prevalence and potential causes of noise problems in outdoor air conditioner units.

2. Previous Work on Sound Generation

Sound can be generally delegated 'sounds' and 'noises'. The sounds that deliver a satisfying impact on the ear are called sounds, while the sounds that create a shaking and undesirable impact are called noises. One individual's sound can be someone else's noise [7]. The sound created when similar impulses are forced to take after each other routinely at an identical spell, with a distinct rhythm with no rapid changes in their amplitudes are called sounds. On top of that, noises mean a complicated nature having irregular periods and amplitudes. There is a difference between these two in that noises are sporadic or sudden, while sounds are nearly smooth, consistent, adjusted and sweet [8].

Vibration is caused by the sound that impacts the ear of a wave-like movement of an elastic medium. Sound is called vibrations that encroach on the eardrum of a human or creature and set up apprehensive disruption. Hence, we require a vibrating object to transmit sound waves and a recipient to take in the energy going through the transmitting medium for us to hear a sound [9,10].

2.1 Physical properties of sound

Noise sometimes becoma an unwanted sound that negatively impacts human and animal life. The loudness and frequency of the sound can vary, and individuals may react differently to the same sound source. Sound is a fluctuation or disturbance in pressure that the human ear can detect. It is generated by the vibration of an object, which creates sound waves that travel through a medium, such as air. The vibration in the air causes an increase in pressure that exceeds atmospheric pressure. Sound is characterised by physical properties such as pitch, intensity, frequency, wavelength and amplitude [11,12]. The density and elasticity of the medium through which the sound travels can affect the speed of the sound waves, with denser and less flexible substances resulting in slower sound wave speed.

At a typical temperature of 20 ^{o}C, sound travels at a speed of 340 m/s in the air [13]. Yang et. al [14] defines frequency as the number of wave oscillations or cycles per second, measured in Hertz (Hz). It is essentially the rate of vibration. One of the most important aspects of the sound system is to act as a frequency analyzer, which determines the amount of energy present at different frequencies in a signal [15]. Noise typically consists of a range of frequencies rather than a single frequency. The human ear can typically detect sounds in the range of 20 to 20,000 Hz, which can contribute to low-frequency noise issues [16]. A frequency of 1 Hz means that the wave oscillates one cycle per second.

2.2 Noise prediction and impact assessment

Noise prediction can be made using mathematical models and simulation software, which can consider various factors such as the unit's location, operating conditions, and the surrounding environment. These models can predict the noise levels generated by the unit under different conditions and can be used to identify the most effective noise reduction measures [17]. Impact assessment, on the other hand, can be done using field measurements and monitoring. Field measurements are used to measure the actual noise levels generated by the unit, and these measurements are compared with the predicted levels [18]. Monitoring can be done over an extended period to assess the long-term impact of the unit on the environment and human health.

Noise prediction models for outdoor air conditioner units are mathematical models used to predict the noise levels generated by the units. These models are essential tools for noise control and management, as they help to predict the noise levels generated by a particular unit and its impact on the environment and human health. The ISO9624-2: 2019 is one of the most common used models for predicting the noise levels of air conditioners' outdoor units [19]. This model is based on the ISO 9614 standard, which provides a method for measuring and assessing noise emitted by mechanical equipment. The model considers the unit's location, operating conditions, and environment. It can predict the noise levels at various distances from the unit.

Noise regulations and standards for air conditioning outdoor units are designed to limit the amount of noise that these units can generate and to protect human health and the environment from excessive noise. These regulations typically specify permissible noise levels for air conditioning outdoor units and may also include testing, certification, and operation requirements [20]. In Malaysia, the Department of Environment (DOE) sets noise regulations and standards for air conditioning outdoor units. According to the DOE, the permissible noise levels for these units are 55 decibels (dB) during the day (between 7 am to 10 pm) and 45 decibels at night (between 10 pm to 7 am) measured at the nearest residential boundary. These levels are based on the International Organization for Standardization standard, which provides a method for measuring and assessing noise emitted by mechanical equipment.

The DOE also requires that all air conditioning outdoor units be tested and certified by a DOE-approved laboratory before being sold or installed in Malaysia. This

is to ensure that the units meet the noise regulations and standards set by the DOE. Any units that do not meet the regulations will not be approved for use and will not be allowed to be installed or used.

3. Methodology

This case study on the noise of outdoor unit air conditioners focuses on determining the sound pressure level data received by a chosen model outdoor unit using a sound level meter as the primary method. The study aims to achieve two objectives: to measure the sound pressure level data received by outdoor unit model DAIKIN Non-Inverter Eco King RN10FV1 using a sound level meter in three modes of operation: fan, cool, and turbo mode and to compare the noise problem caused by the outdoor unit of the air conditioner near the outdoor unit with the standards set by ISO based on the performance of the noise level. The study design includes several stages of work, starting from the beginning of the research.

The first stage includes determining the study's objectives and gathering information related to the literature review. The second stage includes research design, preliminary survey, and survey at the research site using appropriate methods. The third stage includes data collection, data analysis, and then producing the findings of the final report based on the objectives obtained. This methodology includes a thorough and systematic approach to the problem of noise from outdoor unit air conditioners, starting with a clear definition of the objectives, a review of relevant literature, and a comprehensive survey and data collection process. The data collected will then be analysed and compared with the standards set by ISO to provide a comprehensive and accurate understanding of the noise problem and its causes and to develop effective solutions to address the issue.

3.1 Data collection and measurement

As a result of the survey, data measurements were taken twice a day, during the day and at night, from around 12 noon to 2 pm. and 10 pm to 12 pm to measure the noise level near the outdoor unit. Time measurements are made every 3 seconds for 30 minutes. The duration of the data measurement process is two days. The data collected from the sound pressure level is then measured using the following equation.

$$LA_{eq}^{\frac{1}{2}hour} = 10\log 10\left[10\frac{x_1}{10} + 10\frac{x_2}{10} + \cdots\cdots\cdots 10\frac{x_n}{10} / n\right]$$

where, x_1, x_2,., x_n represent the data observed and n is the number of observation

This case study on the noise of outdoor unit air conditioners aims to identify the sound pressure level by using a sound level meter and to compare the noise problem caused by the air conditioner's outdoor unit with the standards set by ISO based on the performance of the noise level. One of the most important parts of this study is data collection. The data that will be collected includes:

i. Sound pressure level data: This data will be collected by measuring the sound pressure level in decibels (dB) using a sound level meter in three modes of operation: fan, cool, and turbo mode. The results will be recorded every 30 minutes for 2 hours. This data will determine the sound pressure level received by the chosen bedroom.

ii. Noise level comparison: Data on the noise level of the outdoor unit air conditioner will be collected and compared to the standards set by DOE and ISO 9614:2:2019 for noise levels in mechanical equipment. This data will determine if the air conditioning unit's noise level meets the standard of DOE and ISO for residential areas.

iii. Location data - The location data includes recording the address and specific location of the observation bedroom and any relevant information about the surrounding area and nearby noise sources. This data will be used to determine if the unit's location is contributing to the noise problem.

iv. Time data - The time data includes recording the date and time of the study, as well as the intervals at which the air conditioning mode is changed. This data will identify the time of the day when the noise level is the highest.

v. Mode of operation - The mode of operation of the air conditioner, including cool, fan, and turbo modes, and the duration of each mode used, will be recorded. This data will be used to determine which mode of operation is causing the highest noise level. Table1 below shows the data collection of the location case study.

Table 1 – Data for location case study and average of SPL

Time	2200
Location	UTHM
Sound Pressure level for Fan mode	68-70 dB
Sound Pressure level for Cool mode	57-60 dB
Sound Pressure level for Turbo mode	68-70 db

Noise level comparison: The noise level of the outdoor unit air conditioner near the outdoor unit was measured, and the average SPL dB like above. Mode of operation: The air conditioner was first operated in fan mode for 30 minutes, then cool mode for 30 minutes, and finally in turbo mode for the remaining hour.

Table 2 – Sample data collection SPL of the location

No	Time	Display Mode	SPL (dB)
1	22:55:17	FAST A110-50	57.3
2	22:55:20	FAST A110-50	57.2
3	22:55:23	FAST A110-50	57.6
4	22:55:26	FAST A110-50	61.3
5	22:55:29	FAST A110-50	57.9
6	22:55:32	FAST A110-50	57.7
7	22:55:35	FAST A110-50	57.5
8	22:55:38	FAST A110-50	57.7
9	22:55:41	FAST A110-50	57.8
10	22:55:44	FAST A110-50	57.8
11	22:55:47	FAST A110-50	57.8
12	22:55:50	FAST A110-50	57.7

4. Results and Discussion

The data obtained from the tests conducted at the study site will be explained more clearly in this chapter: data analysis and results. Through the data and information obtained, the analysis can be carried out to meet the objective requirements that have been previously set in the research, which is number one (1), to measure the sound pressure level data received by outdoor unit model DAIKIN Non-Inverter Eco King RN10FV1 using a sound level meter in three modes of operation: fan, cool, and turbo mode. (2) to compare the noise problem caused by the conditioner's outdoor unit with the standards set by ISO and DOE based on the performance of the noise level. The test method is based on the requirements in the previous chapter.

Therefore, this analysis involves the results of the noise level test using a sound level meter. After that, all the data obtained will be recorded and analysed in detail using Microsoft Excel software to form appropriate tables and graphs to bring the study results.

4.1 Average of external noise level (LA_{eq})

LA_{eq} is common practice to measure noise levels using the A-weighting setting built into all sound level meters. It is the method to describe sound levels with a different value in one specified time, resulting in a single decibel value that considers the total sound energy over the time of interest. LA_{eq} has usually used as a parameter in noise standard calculation. For this research, every 3 seconds was set up within 2 hours and split for 30 minutes for each mode of observation work to record the noise level near the outdoor unit. There was about an average of 1800 to 1900 data for each period.

4.2 Average of external noise level (LA_{eq})

The sound pressure level obtained from the outdoor unit is recorded in tabular form. Each test is conducted for 2 hours of sound pressure level testing, and the first is from 12 noon to 2 pm, where the air conditioning mode will be changed every 30 minutes. The second test is at night. The same test is conducted for 2 hours, from 10 pm until 12 am, and the air conditioning mode will change every 30 minutes. Each data collected is analysed to obtain the minimum value of the lowest sound pressure (*Min*) and the maximum level, the highest sound pressure level (*Max*), along with the LA_{eq} value for each condition. Table 3 shows the sound pressure level data obtained from the measurement.

Table 3 – Results for Sound Pressure Level (SPL) measured.

Time	Mode	Day 1			Day 2		
		LA_{eq} (dB)	L_{max} (dB)	L_{min} (dB)	LA_{eq} (dB)	L_{max} (dB)	L_{min} (dB)
12:00	Cool	**59.70**	62.9	59	**61.31**	63.2	59.1
to	Fan	**71.16**	78.4	62.9	**71.02**	73	65.3
14:00	Turbo	**69.27**	70.9	68.3	**69.20**	70.1	68.1
22:00	Cool	**59.45**	68.5	58.4	**59.55**	68.9	58.7
to	Fan	**69.25**	70.9	68.3	**70.14**	72.3	68.9
00:00	Turbo	**68.45**	69.7	67.6	**69.41**	70.3	68.4

From the table, it shows the noise level during the study, the noise level in LA_{eq} is between 59-71 dB, where the recommended noise limit for air conditioners has been set by the DOE and cannot exceed 68 dB. The noise level recorded in fan mode is the highest compared to the noise level of cool and turbo mode, which reaches up to 71 dB, which is high. The lowest reading is the reading for a cool mode which is 59 dB.

Figure 1 illustrates the noise level of outdoor air conditioning units over two days, from 12 noon to 2 pm. The data shows that the noise level generated by the fan mode on the first day was 71.16 decibels, and on the second day, it fell by a slight amount of 0.14 decibels. Similarly, the noise level generated by the turbo mode on the first day was 68.41 decibels, dropping by a small amount of 0.07 dB on the second day. However, on the second day, it increased by 1.61 dB.

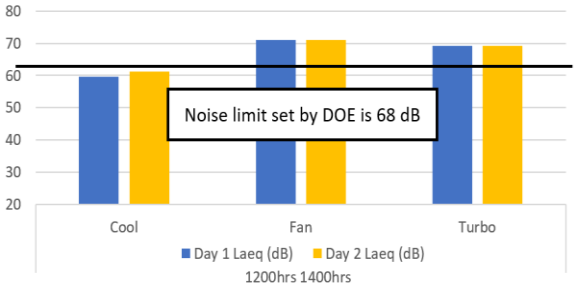
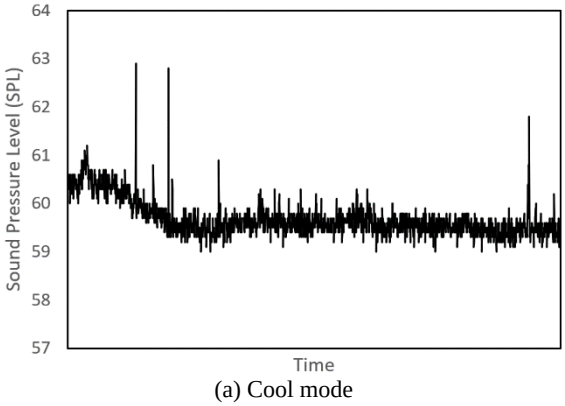


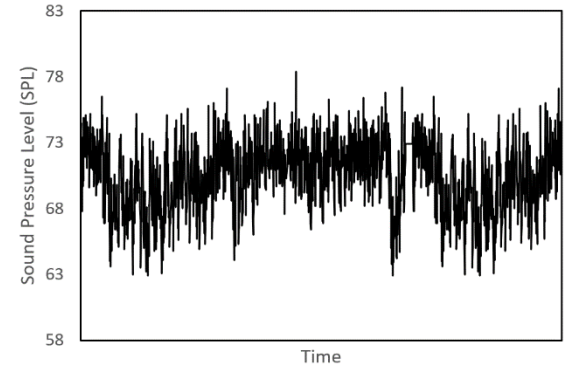
Fig. 1 – Sound Pressure Level results for daytime

It is important to note that the DOE has established specific noise level limits for various types of equipment, including air conditioners, to ensure that they do not cause excessive noise pollution and disturbance to the surrounding community. In this case, the DOE-specified noise level limit for fan and turbo modes is 68 decibels. However, the data from the research shows that the decibel level produced by the outdoor air conditioner unit in fan and turbo modes has exceeded this limit, with a reading of 71.16 dB and 68.41 dB on the first day, respectively.

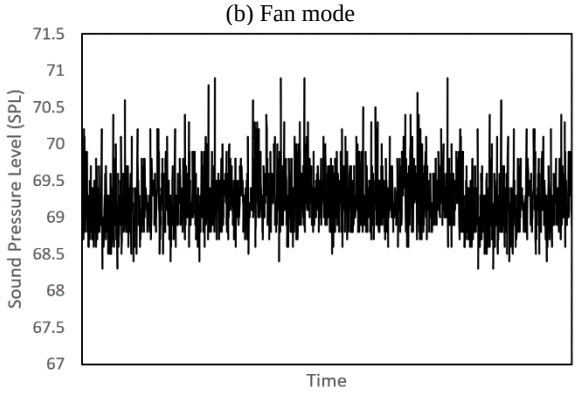
For the cold mode of the air conditioner on both research days remained within the acceptable range set by the DOE, with a noise level of 59.70 dB and 61.31 dB on the first and second days, respectively. This suggests that the noise level produced by the outdoor air conditioner unit in cold mode conforms with DOE regulations and is not causing any disturbance to the surrounding community.



(a) Cool mode



(b) Fan mode



(c) Turbo mode

Fig. 2 – SPL data measurement at daytime for different mode of setting

Figure 3 visually represents the decibel level of an outdoor air conditioner throughout two nights, from 10:00 pm to 12:00 am. The data indicates that the noise intensity in fan mode increased by 0.89 dB from the first night to the second, and similarly, the noise level in turbo mode also rose by 1.04 dB. This means that the decibel level produced by the outdoor air conditioner unit in fan and turbo modes has risen above the acceptable range established by the DOE.

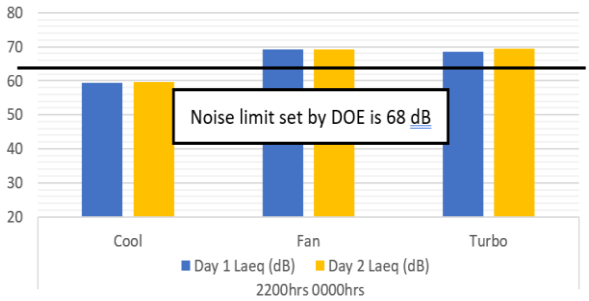
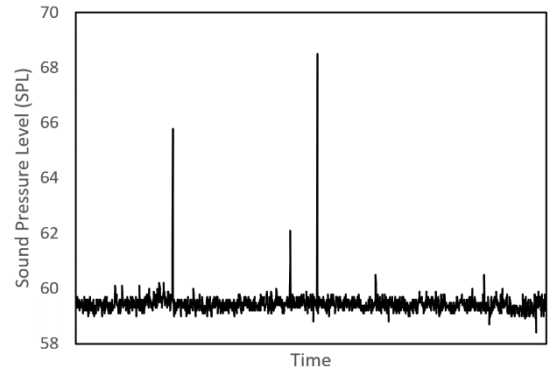


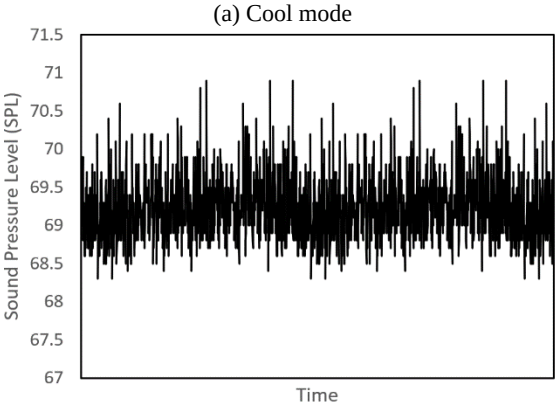
Fig. 3 – Sound Pressure Level results for nightime

It is worth noting that the DOE has set specific noise level limits for various types of equipment, including air conditioners, to ensure that they do not cause excessive noise pollution and disturbance to the surrounding community. The DOE-specified noise level limit for fan and turbo modes is 68.41 dB, respectively. However, the data from the research shows that the decibel level produced by the outdoor air conditioner unit in fan and turbo modes has exceeded this limit, with a reading of 69.25 dB and 70.14 dB, respectively.

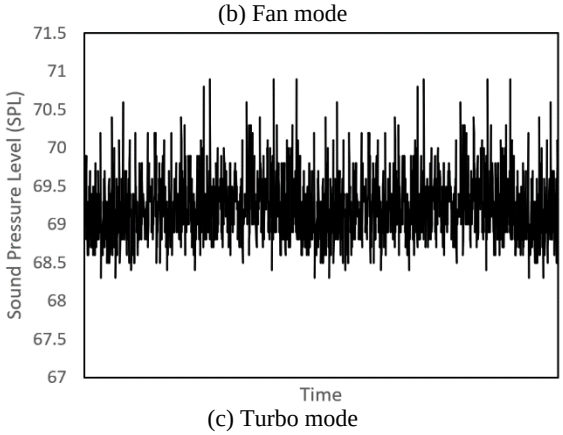
On the other hand, the cold mode of the air conditioner during both nights of the research remained within the acceptable range set by the DOE, with a noise level of 59.45 dB and 59.55 dB on the first and second nights, respectively. This suggests that the noise level produced by the outdoor air conditioner unit in cold mode is acceptable and within the limit set by the DOE.



(a) Cool mode



(b) Fan mode



(c) Turbo mode

Fig. 4 – SPL data measurement at nighttime for different mode of setting

Figures 1 to 4 shows that the noise level and criteria of the outdoor air conditioner unit were evaluated in three different modes: cool, fan and turbo. The results revealed that only the cool mode met the established standards and regulations of the DOE and the International Standards Organization for air conditioners. These standards specify that the allowed noise level should not exceed 68 dB. However, the noise level readings for both fan and turbo modes were significantly higher, especially the fan mode, which reached an LA_{eq} reading of 71.16 dB.

This indicates that the fan and turbo modes of the outdoor air conditioner unit exceed the established standards and regulations and may cause excessive noise pollution and disturbance in the surrounding community. Therefore, it is recommended to take the necessary steps to bring the noise level of fan and turbo modes within the acceptable range, to ensure compliance with the standards and regulations set by the DOE and ISO, and to prevent any disturbance to the surrounding community.

5. Conclusion

The objectives of this study was to measure the sound pressure level data produced by the chosen model of the outdoor unit using a sound level meter in three modes of operation: fan, cool, and turbo mode. The results of these measurements confirmed that the cool mode follows the standard, but the fan and turbo modes do not, with noise levels exceeding 68 dB. This was a significant finding as it shows that a significant source of noise disturbance is caused by the air conditioner's outdoor unit in the fan and turbo modes. The comparison of the data collected from the sound level meter with the ISO standards revealed that the noise levels emitted by the outdoor unit of the air conditioner in fan and turbo modes do not meet the standard.

This confirms the findings of the sound pressure level data measurements and highlights the significant noise problem caused by the outdoor air conditioner in the chosen bedroom. Overall, this study has contributed to understanding the noise problem caused by an outdoor air conditioner that does not meet DOE and ISO standards. The results of this study provide a solid foundation for future research in this area and can be used to inform the development of policies and strategies to address this problem.

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