The Impact of PM2.5 on Socio-Economic of Thailand: The Perception Based on The Survey Data

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Received: September 22, 2022 *Revised: March 20, 2023* *Accepted: March 27, 2023*

Abstract

The current fine particulate matter (PM2.5) situation in Thailand becomes urgent as a national issue. The impacts from dust do not be limited only dust particle itself but it also carried various toxins. Many studies have determined that PM2.5 contains various heavy metals that result in health problems. The health dimensions that could be affected by PM2.5 include respiratory tract diseases, mental health, well-being, etc. These impacts affect working people, as well as society in various living conditions covered urban and rural setting. This paper aims to investigate PM2.5, focusing on its health and economic impacts. The data has been collected by using questionnaire which was

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distributed in all province of Thailand Kingdom. The perceptions of Thai people regarding impacts from PM2.5, including economic, social, and environmental impacts, have been determined using a mathematical model to interpret as empirical values for perception levels among different groups of factors studied. The study used the Multiple Indicator and Multiple Cause (MIMIC) model to analyze the data in such a way that the variables could be observed. Multiple observed variables can predict or affect latent variables. According to the findings, people are more likely to focus on PM2.5 when they are middle-aged or older, when they have more knowledge and experience, and people with families are more aware of PM2.5 dust, which not only affects health but also has a significant social and economic impact, especially massive social impact.

Keywords: PM2.5, Socio-Economy, Mental Health, Well-being

ผลกระทบของ PM๒.๕ ต่อเศรษฐกิจและสังคมของประเทศไทย: การรับรู้จากข้อมูลการสำรวจ

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บทคัดย่อ

สถานการณ์ฝุ่นละอองขนาดเล็ก (PM2.5) ในประเทศไทยในปัจจุบันกลายเป็นประเด็นเร่งด่วนระดับชาติ ผลกระทบจากฝุ่นไม่ได้จำกัดเพียงอนุภาคฝุ่นเท่านั้น แต่ยังนำพาสารพิษต่างๆ อีกด้วย งานวิจัยหลายชิ้นระบุว่า PM2.5 มีโลหะหนักหลายชนิดส่งผลให้เกิดปัญหา มิติด้านสุขภาพที่อาจได้รับผลกระทบจาก PM2.5 ได้แก่ โรคทางเดินหายใจ สุขภาพจิต และ ชีวิตความเป็นอยู่ที่ดี ผลกระทบเหล่านี้ส่งผลต่อการงานตลอดจนสังคมในสภาพความเป็นอยู่ที่หลากหลายครอบคลุมทั้งในเมืองและในชนบท บทความนี้มีวัตถุประสงค์เพื่อตรวจสอบ PM2.5 โดยเน้นที่ผลกระทบ

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ด้านสุขภาพ สังคม และ เศรษฐกิจ ในการศึกษาครั้งนี้ ได้รวบรวมข้อมูลโดยใช้แบบสอบถามในการเก็บข้อมูลในประเทศไทย การรับรู้ของคนไทยเกี่ยวกับผลกระทบจาก PM2.5 ทั้งผลกระทบทางเศรษฐกิจ สังคม และสิ่งแวดล้อม การศึกษาครั้งนี้กำหนดขึ้นโดยใช้แบบจำลองทางคณิตศาสตร์ เพื่อตีความเชิงประจักษ์สำหรับระดับการรับรู้ด้าน PM2.5 กับกลุ่มปัจจัยต่างๆ ที่มีผลต่อระดับการรับรู้ด้าน PM2.5 ซึ่งในการศึกษาครั้งนี้ได้ใช้แบบจำลอง MIMIC ในการวิเคราะห์ข้อมูลในลักษณะที่สามารถวิเคราะห์ตัวแปรตามได้หลายตัว และยังสามารถทำนายตัวแปรตามดังกล่าวจากผลกระทบของตัวแปรแฝง หรือ ตัวแปรอิสระอื่น ๆ ได้ จากผลการวิจัยพบว่า คนไทยมีแนวโน้มที่จะให้ความสำคัญกับ PM2.5 มากขึ้นเมื่อพวกเขาเริ่มเข้าสู่วัยกลางคนขึ้นไป ซึ่งบ่งชี้ว่าเมื่อพวกเขามีความรู้และประสบการณ์มากขึ้นเขาจะให้ความสำคัญในเรื่อง PM 2.5 มากขึ้น มากกว่านั้นคนไทยที่มีครอบครัวจะตระหนักถึงผลร้ายของฝุ่น PM2.5 มากกว่ากลุ่มอื่น ๆ โดยตระหนักว่า PM 2.5 ไม่เพียงแต่ส่งผลต่อสุขภาพเท่านั้น แต่ยังมีผลกระทบต่อสังคมเศรษฐกิจ โดยเฉพาะอย่างยิ่งตระหนักว่าด้านสังคมได้รับผลกระทบอย่างมากจาก PM 2.5

คำสำคัญ: PM2.5 สังคม-เศรษฐกิจ สุขภาพ ชีวิตความเป็นอยู่ที่ดี

Introduction

The current fine particulate matter (PM2.5) situation in Thailand becomes urgent as a national issue. The impacts from dust do not be limited only dust particle itself but it also carried various toxins. Studies (Luo, H., 2020) have determined that the PM2.5 contains various heavy metals, which result in health problems. The health dimensions that could be affected by PM2.5 include respiratory tract diseases, mental health, well-being, etc. These impacts affect working people, as well as society in various living conditions in urban and rural settings, because when there is a problem with PM2.5 dust, it will result in being unable to travel. Or unable to go out to do outside activities like it used to be and affecting the people working because when the dust problem occurs Working people will be affected, especially those who work outdoors. This paper aim to investigate the impact of PM2.5, focusing on health and economic impacts. The data has been collected by using questionnaire which was distributed in all province of Thailand Kingdom. The perceptions of Thai people regarding impacts from PM2.5, including economic, social, and environment have been determined using a mathematical model which is a multiple regression model. The model used is better than general multiple regression, which is a model with only one variable, latency The latent factor was influenced by several externally observed variables. and many internal variables in other words, it is a multi-causal model of latent traits and measured by multiple indicators and interpreted as empirical values for perception levels among different groups of factors studied. which were the expected results of the study. To know how much Thai people are aware of or are aware of the problem of PM2.5 dust and extent are they aware of their health impacts level.

Literature review

Air Quality of PM2.5

Human health of PM2.5

The deterioration of air quality, raising worldwide concerns. PM2.5 (particles less than 2.5 micrometers in diameter) can penetrate deeply into the lung, irritate and corrode the alveolar wall, and consequently (Liu, C., Chen, 2019). In the analysis of PM2.5, we observed an increase of 0.68% in all-cause mortality per 10-μg-per-cubic-meter increase in PM2.5 concentration and found that the associations of mortality with PM concentrations were slightly stronger with PM2.5 than with PM10 in most countries and regions, which added to the evidence that PM2.5 accounted for a larger proportion of the effects of PM10 and PM2.5 combined. And the stronger effects of PM2.5 may also

be supported by the abundant evidence that this particulate fraction contains more small particles that can absorb toxic components from the air and penetrate deep into the lungs that penetrates and settles deep into the alveoli and can result in damage to the respiratory system (Liao, Q.,2020). Moreover, the issue of viral disease outbreaks, some of which may be linked to air pollution, cannot be overlooked. Several studies have reported a link between air pollution and the spread of viral infections, as viruses can be suspended in the air by attaching to sputum particles or the particulate matters in the air (Cao et al, 2014; Su et al, 2019). It was found that if the levels of PM10 and PM2.5 increased, it would result in a higher rate of viral infection and case fatality from infection has increased accordingly (Comunian et al, 2020; Fattorini and Regoli, 2020; Li et al, 2020; Yao et al, 2020). Air pollution has become a global health problem. However, there are many obstacles to eliminating air pollution because of the large number of air pollutants, insufficient funding for monitoring and reduction programs, and the political and social challenges in determining policies to limit emissions (Xie, Dai, Dong, 2016)

Perception

Economics Impact from PM2.5

The health-related economic loss caused by PM2.5 pollution accounted for a high proportion in the GDP, highlighting the severity of the health effects caused by PM2.5 pollution (Adams, M.D., 2016). In areas with high concentrations of PM2.5, PM2.5 pollution-related diseases cause additional medical expenses, work time loss and GDP loss (Yang, Y., Fang, 2021)

Social Impact from PM2.

Pregnant women or those who are physically susceptible to exposure to dust or air pollution will have a significant adverse effect on their health compared to the general population. And according to the article, there is a Clean Air Act category for the prevention of PM2.5 dust-risk groups to protect pregnant women. and vulnerable groups that have been affected by such situations and groups whose populations have poverty problems are protected as well. which has helped these people (Koman, P. D., Hogan, 2018)

Environmental Urban Impact from PM2.5

Smog and air pollution have fast become significant environmental problems and are attributed to rapid global industrialization and urbanization (Liu, S., Chiang, 2018) when the city expands more Resulting in the problem of PM2.5 dust, which has a negative impact on the community and on the urban environment (Martins, N. R, 2018) PM2.5 particulate matter is a pollutant found in

every area. Every environment whether in the city or in the countryside Most of them are caused by Transportation. And domestic fuel combustion which significantly affects the health of people living in the city (Han, L., Zhou, 2015)

Environmental Rural Impact from PM2.5

PM2.5-related deaths were found to be significant in both urban and rural areas due to inhalation. and there is exposure in California (Garcia, C. A., 2015)

Methodology

This study used the Multiple Indicator and Multiple Cause (MMIC) model to analyze the data in such a way that the variables could be observed so that multiple observed variables could predict or affect latent variables. The simplest MIMIC model has observable variables (x-variables). Multiple variables can be predicted, or they can affect one latent variable (Eta), where latent variables are measured by indicators. (y-variables) with many variables in which this characteristic analysis reveals the results of observable variables. Each variable has a distinct effect on the latent variable.

The conceptual framework of MIMIC model

MIMIC model Equation Form which can be viewed in full as follows: (Jöreskog and Goldberger, 1975):

$$y* = \alpha' x + \epsilon \quad (1)$$

$$y = \beta y* + u \quad (2)$$

Where $y = (y1, y2, \dots, y_p)'$ are indicators of the latent variable y^* and $x = (x1, x2, \dots, x_p)'$ are causes of y^*.

This model is based on (Jöreskog and Goldberger, 1975):

$$E(\epsilon u') = 0', E(\epsilon^2) = \sigma^2, E(uu') = \Theta^2 \ (3)$$

MIMIC models, typically, also make distributional assumptions, for example that the joint distribution of the variables is Gaussian, the relation is linear, and each measured variable and each latent common cause has specific sources of variance that are independent of the sources of variance specific to other variables. If x and y are in an endogenous relationship, for example, if both have an influence on each other (so-called reverse causality), the assumptions in (3) are refuted. In this case,

it is also impossible to identify the relationships in (1) and (2). Deriving from (1) and (2), the reduced form model and formula for variance-covariance matrix is described in (Jöreskog and Goldberger, 1975): In equation 4. y is Economics, Environmental rural, Environmental urban, Health, Social. Can see table 1

$$y = \beta(\alpha' x + \epsilon) + u = \Pi' x + v \quad (4)$$

$$\Pi = \alpha\beta' \quad (5)$$

$$v = \beta\epsilon + u \quad (6)$$

$$\Omega = E(vv') = E[(\beta\epsilon + u)(\beta\epsilon + u)'] = \sigma^2\beta\beta' + \Theta^2 \quad (7)$$

The formulas for the MIMIC parameters (α, β, Θ) cannot be expressed in closed form. Implicit forms can be derived following as: In Equation 8 to 10 $\hat{\alpha}, \hat{\beta}, \hat{P}$ are parameter to estimate for MIMIC model and Equation 11 to 13 in a term of X can see table 1

$$\hat{\alpha} = \left(\frac{1}{\hat{\kappa}2}\right)P\hat{\Omega}^{-1}\beta = \left(\frac{1}{\hat{\pi}2}\right)\hat{P}\Theta - 2\beta \quad (8)$$

$$[S + \left(\frac{1}{\hat{\kappa}2}\right)Q]\hat{\Omega}^{-1}\beta = (1 + \hat{\rho}^2)\beta \quad (9)$$

$$\pi^2 = \beta'\Theta^{-2}\beta, \kappa^2 = \beta'\Omega^{-1}\beta = \frac{\pi 2}{(1 + \pi 2)} \quad (10)$$

$$P = (X'PXX)^{-1}X'PXY, Q = Y'XP \quad (11)$$

$$S = (Y - XPXP)')(Y - XPXP) = Y'(I - XPX(X'PXX) - 1PXX')Y \quad (12)$$

$$PX = X(X'X) - 1X' \quad (13)$$

To derive the properties of a new estimator able to correct for the violation of the assumptions in (3) due to endogeneity in the model, we use the method of the analysis of covariance structures and the proposal from to transform the MIMIC model into a covariance structure modelling framework. develops a general covariance structure model for a multivariate normal vector z as:

$$E(z'z) = \Sigma = B(\Lambda\Phi\Lambda' + \Psi 2)B' + \Theta^2 \quad (14)$$

$$E(z) = A\Xi P \quad (15)$$

where $E(z'z)$ is the covariance matrix of MIMIC model and also $E(z)$ is the variance matrix of MIMIC model.

Where A is an N×g matrix of rank g and P is a h×p matrix of rank h, both being fixed matrices with g≤N and h≤p; Ξ, B, Λ, the symmetric matrix Φ, and the diagonal matrices Ψ and Θ are parameter matrices.

Based on the model in (14) and (15), Jöreskog derives the log-likelihood function as: In an equation 16 is the log-likelihood function of all parameters in MIMIC model need to estimate by maximum likelihood estimator *(*MLE*)*. The equation 17 is a covariance of error term for MIMIC model.

$$\log L = -\frac{1}{2}pN\log(2\pi) - \frac{1}{2}N\log|\Sigma| - \frac{1}{2}\sum_{a=1}^{n}\sum_{i=1}^{p}\sum_{j=1}^{p}(x_{ai} - \mu_{ai})\,\sigma^{ij}\left(x_{aj} - \mu_{aj}\right) \quad (16)$$

where μ_{ai} and σ^{ij} are elements of $E(X)=A\Xi P$ and Σ^{-1}, respectively. Writing

$$T = \frac{1}{N}(X - A\Xi P)'(X - A\Xi P) \quad (17)$$

we can readily see that maximizing log$L$ is equivalent to minimizing in equation 18

$$F = \log|\Sigma| + \mathrm{tr}(T\Sigma^{-1}) \quad (18)$$

For MIMIC model, taking $z= (x', y')$ we have in the random case in equation 19

$$\Sigma = \begin{pmatrix} \Phi & \Phi\alpha\beta' \\ \beta\alpha'\Phi & (1+\rho^2)\beta\beta' + \Theta^2 \end{pmatrix} \quad (19)$$

This covariance structure of MIMIC model may be specified in terms of Jöreskog's model by setting follow equation 20

$$B = \begin{pmatrix} Ik \times k & 0k \times 1 \\ 0m \times k & \beta m \times 1 \end{pmatrix}, \Lambda = \begin{pmatrix} Ik \times k \\ \alpha'_{1\times k} \end{pmatrix},$$

$$\Psi = \begin{pmatrix} 0_{k\times k} & 0_{k\times 1} \\ 0_1 \times k & \beta_{m\times 1} \end{pmatrix}, \Theta = \begin{pmatrix} 0_{kxk} & 0_{kxm} \\ 0_{mxk} & \Theta_{mxm} \end{pmatrix} \quad (20)$$

and taking Φ free (Jöreskog and Goldberger, *1975).*

As our parameters and estimator cannot be expressed in closed form, we adopt a solution from (Jöreskog and Sorbom, 1993) to estimate equations from the latent variable model

This research design was cross sectional survey to explore the perception of Thai people regarding to PM2.5 impacts. The survey has been implemented in all province with sample number calculated and using random sampling technique to reach the sample. The research was done during April - August 2021

Sampling technique

The sample number was calculated by calculating the number of unknown cases of W.G. Cochran, 1953 with a 95 percent confidence level and a 5% error level defined.

Formula $$n = \frac{P(1-P)(Z)^2}{d^2}$$

by n is the required number of samples

P is the proportion of the population.

Z is the specified level of confidence or the level of statistical significance.

d is the proportion of the tolerance that can occur.

Substituting $$n = \frac{0.5(1-0.5)(0.95)^2}{0.5^2}$$

$$= \frac{0.9025}{0.0025}$$

$$n = 361$$

The sample size required to collect data was 361 samples, but the researcher collected all 521 samples to facilitate the analysis.

Research tool

The questionnaire was developed to be used for data collection. The first draft of questionnaire was validated by experts in the fields of economics, health, social sciences and environmental sciences. The questions were adjusted in according to the comments obtained before using.

Conceptual model and analysis

This study seeks to quantify the influence of PM 2.5 on Thailand's socioeconomics using the MIMIC (Multiple Indicator Multiple Cause) methodology. The approach and conceptual framework were developed based on this following paradigm. (See more details in figure 1 and in topic 5.1)

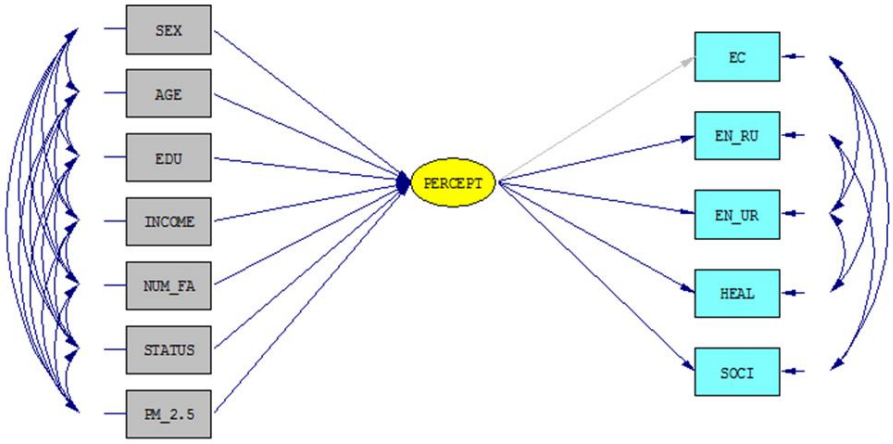

Figure 1: Display the conceptual framework of MIMIC (multiple indicator multiple cause) model to quantify the perception of The Impact of PM2.5 on Socio-Economic of Thailand

The Multiple Indicators and Multiple Causes (MIMIC) model is the analysis of data in such a way that many observed variables can predict or affect latent variables. Latent variable the simplest form of the MIMIC model is observable variables. x-variables where the variable x is sex, age, education, income, number of children, status, and PM2.5, which these variables can predict or affect one latent variable (Eta), where latent variables are measured by indicators. Multiple variables (y-variables) are defined. The Y variables are economics (EC), environmental rural (EN_RU), environmental urban (EN_UR), health (HEAL), and social (SOCI). See table 1

Table 1: Variable and Definition

X variables	
Variable name	**Definition**
SEX	Men, Women
AGE	Age
EDU	Education
INCOME	Income
NUM_FA	Number of family
STATUS	Status
PM_2.5	Perception PM2.5
Y variables	
Variable name	**Definition**
EC	Economic
EN_RU	Environmental rural
EN_UR	Environmental urban
HEAL	Health
SOCI	Social

Results and discussions

Characteristic of respondents

The characteristics of respondents described by descriptive statistics was presented in Table 2. The max-min values of aging were 78 and 14 years old respectively, with the average age was 31 years old. The average income was 22,860 Baht/month whereas the maximum income reported was 300,000 Baht/month which revealed the high standard deviation (27,902). Some samples reported that they had no income. The mean number of families is 3.32, the maximum value is 15, and the lowest value is 1. The male was accounting for 176 whereas female was accounting for 345 of the total number of respondents. Most of the respondents graduated a bachelor's degree, which was 256, postgraduate was 107, high school was 95, and vocational certificate was 6 persons, respectively.

Table 2: Descriptive statistics of respondents.

Variable	Count	Max	Min	Mean	STD
Age	520	78	14	30.5	11
Income	521	300000	0	22860	27902
Num_Family	519	15	1	3.33	1.62
	Description	**Count**	**Proportion**		
Sex	Men	176	33.78%		
	Women	345	66.22%		
Status	Have a family	155	29.75%		
	No family	366	70.25%		
Education	High school or equivalent	95	18.23%		
	Diploma/High Vocational	63	12.09%		
	Bachelor's degree	256	49.13%		
	Postgraduate	107	20.53%		
PM2.5 Impact	very little	3	0.61%		
	little	9	1.83%		
	moderate	98	20.00%		
	high	212	43.26%		
	highest	168	34.29%		

Based on the questionnaire response, the number of respondents who has no family was 366 whereas 155 is respondent married or have a family. The perception level regarding the severity of PM2.5 Impact was 4 to 5 (from 5 of full scale). The frequency of perception levels at 4 (high) and 5 (highest) were 212 and 168 respectively.

The perspective of respondents regarding PM 2.5 impacts

as shown in Table 3, the majority of respondents indicated that the impact of PM2.5 on health was greatest (level 5), accounting for 39.5% of the total 458 respondents.

Table 3: The perception levels of impacts from PM2.5

	Description	Count	Proportion
Health_Impact	very little	4	0.87%
	little	17	3.71%
	moderate	109	23.80%
	high	147	32.10%
	highest	181	39.52%
Economic_Impact	very little	18	4.15%
	little	57	13.16%
	moderate	163	37.64%
	high	118	27.25%
	highest	77	17.80%
Social_Impact	very little	6	1.31%
	little	34	7.42%
	moderate	140	30.56%
	high	173	37.77%
	highest	105	22.92%
Envi_Rural_Impact	very little	5	1.07%
	little	15	3.23%
	moderate	144	31.03%
	high	182	39.22%
	highest	118	25.43%
Envi_Urban_Impact	very little	3	0.62%
	little	6	1.25%
	moderate	102	21.25%
	high	178	37.08%
	highest	191	39.80%

While the perception of health impacts from PM2.5 has mostly fallen to its highest level, most respondents perceived that the severity of the impact of PM2.5 on the economy was 3. The number was 163, which accounted for 37.6% of the total samples from the 433 respondents. The level of social impact in most Thais' perceptions was 4 (173, or 39.2% of the total 458 respondents). The perceptions regarding the environmental impact of PM2.5 in rural and urban areas were 4 and 5, respectively, which reflect the critical problem in an urban context. 39.2% respondents from total 464 respondents. mentioned that the severity level in rural area was 4 while the urban area has been facing more critical with perception level at 5 from 191 responses which account 39.8% of total 480 respondents.

The empirical result of estimation of MIMIC model

The results of empirical analysis show that the variable x is defined, which is the initial variable. Several variables were defined, namely sex, age, education, income, Num family, status, and

PM2.5, of which seven variables influenced perceptions, which values were the most influenced or the values that people perceived most, see figure 2.

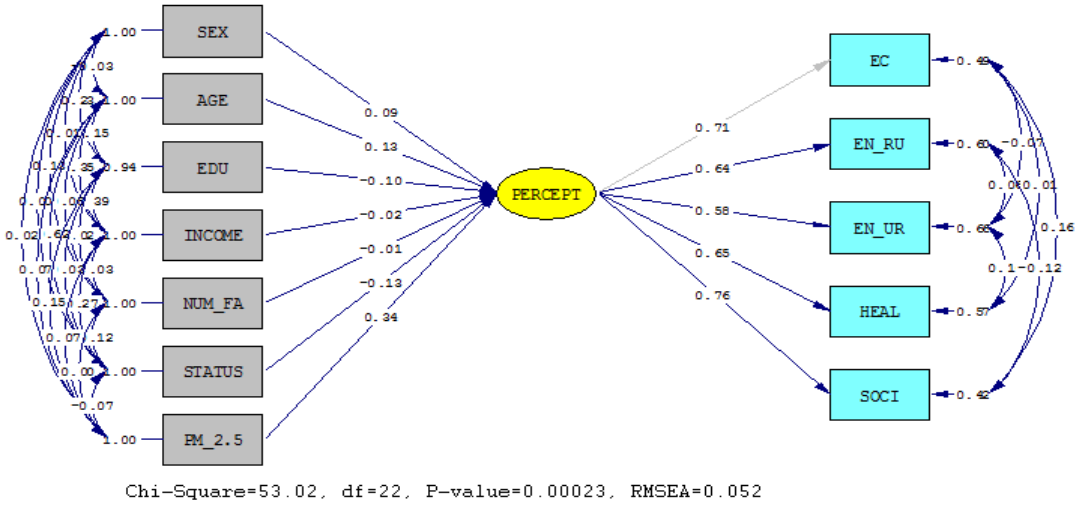

Figure 2: Result of MIMIC (multiple indicator multiple cause) model to quantify the perception of The Impact of PM2.5 on Socio-Economic of Thailand

The factors include perception of PM2.5, which is 0.34, followed by age, which is 0.13, and sex is 0.09, and Num family is -0.01, where income is -0.02, education is -0.10, and status is -0.13 respectively. For the Y variable analysis, Percept selected Social with the highest value, which was 0.76, Economics was 0.71, Health was 0.65, and Environmental rural was 0.64, and Environmental urban was 0.58, respectively. The analysis of the Y variable showed that people were first interested in social issues, followed by economic and health issues, and the rural environment and the environment within the city, respectively. The above data reflects that people are aware of the rural environment that needs to be clean without any pollution. This may be because the countryside is a peaceful area, which should not have dust problems.

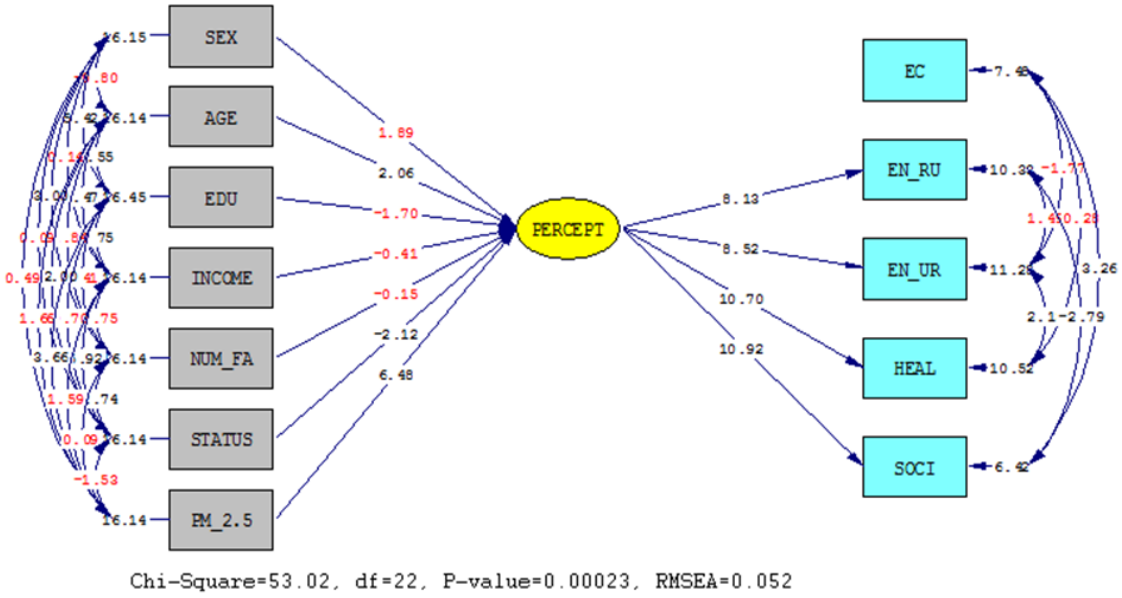

Figure 3: Result t-value of MIMIC (multiple indicator multiple cause) model

Table 4: The estimation results for the parameters and t-value in the MIMIC model.

X-Variables	β	**t**
SEX	0.09	1.89
AGE	0.13	2.06
EDU	0.10	-1.70
INCOME	-0.02	-0.41
NUM_FA	-0.01	-0.15
STATUS	-0.13	-2.12
PM2.5	0.34	6.48
Y-Variables	**Perception**	
	β	**t**
EC	0.71	-
EN_RU	0.64	8.13
EN_UR	0.58	8.52
HEAL	0.65	10.70
SOCI	0.76	10.92

χ^2=53.02, df=22, RMSEA=0.052, RMR=0.036, SRMR=0.036, GFI=0.98, AGFI=0.94, NFI=0.97

From the analysis of the t-value (See Figue3) , it is evident that there were three main significant variables: PM2.5 was 6.48, the highest value, and AGE was 2.06, and Status was -2.12, respectively. High is the perception of PM2.5, which is related to age. As people get older, people are significantly more interested in PM2.5. The data shows that the status of the person has a family will be interested and aware of the problem of dust more than those who are single.

Conclusions

The problem of PM2.5 dust has a significant impact on health and on society and the economy. Based on the MIMIC analysis, it is revealed that people are aware of and value social, economic, and health issues. From the MIMIC model analysis results, it is clear that people focus and focus on PM2.5 during the age of middle-aged people or people who are old, who may have knowledge and experience, and people with families will be more aware of PM2.5 dust than single people, which from perception means that people are interested in social impact problems first. This may be because if there is a problem with dust, it may cause social turmoil and leave no livable scenery. The second one that raises awareness is problems affecting the economy and problems affecting health. which not only affects health but also has a significant social and economic impact. These three factors It is a factor that the government and related agencies should raise awareness about to take part in solving the problem of dust.

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