DOI: 10.2478/jwld-2019-0048



JOURNAL OF WATER AND LAND DEVELOPMENT
2019, No. 42 (VII–IX): 83–90
PL ISSN 1429–7426, e-ISSN 2083-4535

Available (PDF): http://www.itp.edu.pl/wydawnictwo/journal; http://www.degruyter.com/view/j/jwld; http://journals.pan.pl/jwld

Received 17.11.2018
Reviewed 29.01.2019
Accepted 04.03.2019

**A** – study design
**B** – data collection
**C** – statistical analysis
**D** – data interpretation
**E** – manuscript preparation
**F** – literature search

# Applied structural equation model in sustainable development of water resources management

**Ang Kean HUA**[1), 2)] **ABCDEF** ✉

[1)] Quest International University Perak, Faculty of Science and Technology, School of Biological Sciences, No. 227, Plaze Teh Teng Seng (Level 2), Jalan Raja Permaisuri Bainun, 30250 Ipoh, Perak Darul Ridzuan, Malaysia
[2)] Universiti Putra Malaysia, Faculty of Environmental Studies, Department of Environmental Sciences, 43400 UPM Serdang, Selangor, Malaysia
orcid.org/0000-0002-2479-4111; e-mail: keanhua.ang@qiup.edu.my

**For citation:** Hua A.K. 2019. Applied structural equation model in sustainable development of water resources management. Journal of Water and Land Development. No. 42 (VII–IX) p. 83–90. DOI: 10.2478/jwld-2019-0048.

**Abstract**

River water pollution has been reported globally. In suggestion to adapt sustainability approach, this study carry out to tests the structural equation model between sustainable development and water resources management in the Malacca River basin (Malaysia). The model consists of six latent constructs (anthropogenic activities; law, regulation and policy; land and water ecosystem; Malacca River; river water pollution; sustainability) and twenty four items based on 400 questionnaires which were completed and returned by the local residents of Malacca state. Selected study area is within Malacca River basin. The result show the Malacca River is influenced by water law-regulation-policy ($\beta = 0.546$, $p < 0.001$), anthropogenic activities ($\beta = 0.145$, $p < 0.001$), river water pollution ($\beta = 0.142$, $p < 0.001$), land and water ecosystem ($\beta = 0.105$, $p < 0.01$), as well as sustainable approach ($\beta = 0.127$, $p < 0.5$). It was found that a sustainable approach and water law-regulation-policy have a direct influence on anthropogenic activities, river water pollution, as well as the land and water ecosystem. In conclusion, this study suggests developing an earlier approach of the model involved with water resources management and sustainable development.

**Key words:** *Malacca River basin, local residents, sustainable approach, water law-regulation-policy*

## INTRODUCTION

The river basin has become the major water supplier for various purposes such as drinking, domestic, transportation, recreation, power generation as well as the fertile lands for agriculture activities, which have become a highly concentrated population-residential area [HU *et al.* 2012; MOURI *et al.* 2011; MUSTAPHA *et al.* 2013; VENKATRAMANAN *et al.* 2014]. Since river water quality is an interrelated, therefore, the water will easily be influenced by local and temporal variations as well as the volume of water flow [MANDAL *et al.* 2010]. Most researchers claimed that the river water was contaminated due to wastewater discharges of degradable organics, nutrients, domestic effluents, and agricultural waste, which originated from the activities of urban, industrial, and agriculture that flows into the surface and subsurface waters [BARAKAT *et al.* 2013; HUA 2017; HUA *et al.* 2016; MISHRA *et al.* 2016; REZAEI, SAYADI 2015].

Human population growth and economic activities had increased on a large scale; which doubled the demand for water supply for various users. The improper management of resources plus water pollution had impacted in the decline of quality and quantity of surface water resources [HOSSAIN, BAHAUDDIN 2013; MUSTAPHA *et al.* 2013; VENKATRAMANAN *et al.* 2014]. Apart from industrial and agricultural activities, the urbanisation process with inadequate and proper planning in many cities of developing countries had increased the water pollution by dumping wastes including bathing and washing into the open surface water body [CUKROV *et al.* 2012]. The deterioration of water quality will affect the human health and animal ecosystem [KOPACZ, TWARDY 2012]. Therefore, it is important to investigate and determine a possible solution for water contamination through a sustainable development approach in river basin management by developing an appropriate structural equation model.

Sustainable development can be defined as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs; which is compulsory to contain two main key concepts such as (1) the essential needs of the poor should be given priority, and (2) the social organisation and the technology should limit on the usage of the environment's ability to meet present and future needs [WCED 1987]. Based on the definition of sustainable development, the conceptual plan can be divided into three domains, namely the environment, the economy, and the society [PASSET 1979]; before it is further divided into four sub-domains of social-ecology, economics, politics and culture [JAMES 2014]. In general, the environmental value moves forward and becomes important in determining the economics and society worldwide. In other words, the ecology becomes an intersection between the social and nature, before economics and politics play a role in the development of a country. Therefore, environmental sustainable development should be conserved and preserved to reduce and to avoid continuous destruction of the natural resource which provides an improvement for human quality life in the future. Nevertheless, river water contamination, which is considered as one of the environmental elements, is suspected to have correlated with population and economic growth is increasing drastically [HUA 2017; HUA *et al.* 2016; MISHRA *et al.* 2016; REZAEI, SAYADI 2015]. Although, rapid urbanisation had positively benefitted the economic and political view, but indirectly had caused river pollution resulting to a decline in ecological health.

Several studies had been conducted using a sustainable development approach on water resources development [LIU *et al.* 2012; NEL *et al.* 2011; TIWARI, JOSHI 2012], and water resources management [LOUCKS 2000; MARIOLAKOS 2007; PAHL-WOSTL *et al.* 2008]. Majority of the studies were conducted with the vision and mission to sustain the quality and quantity of water resources which are important for continuous survival in the future generation. Most of the studies carried out on water resources to identify the environmental issues that exist when water pollution is detected, together plus with the drastic climate change (the frequent dry and flood season) as well as the increased demand for water supply for the rapid population growth and socio-economic view, resulting to the crisis of water for drinking and irrigation activities [LIU *et al.* 2012; LOUCKS 2000; MARIOLAKOS 2007; NEL *et al.* 2011; PAHL-WOSTL *et al.* 2008; TIWARI, JOSHI 2012]. Therefore, this study suggested for a sustainable development in water resources development by (1) increasing the area for forest with the purpose of recharging, replenishing and regenerating freshwater which are involved with the issues of dwindling water resources; (2) conversion of marginal and submarginal cultivated land into forest would facilitate the desired conservation of water and other natural resources; (3) rehabilitation and development of degraded land by reforestation and afforestation, planting of water conserving and fuel-wood and fodder providing species would increase biomass productivity as well as improve water availability to the rural regions; as well as (4) other factors such as water pollution control, reservoir project, water reuse and water saving propaganda [LIU *et al.* 2012; TIWARI, JOSHI 2012].

Meanwhile, the study conducted on water resources management suggested several methods to sustain the natural resources, which are (1) increasing efficiency in water use for agriculture activities through irrigation project, for industrial use on water by resorting to clean technology and recycling practices, as well as domestic water supply by using treated water; (2) decreasing or avoiding continuous surface water quality pollution worldwide, which could also reduce possible soil contamination and groundwater pollution that provides negative effects to ecosystem; (3) introducing basic law and regulation for the usage of water resources, as well as producing the pollution levels based on the standards for effluent characteristic parameters; (4) the basic knowledge through education and training on management courses which plays an important role to succeed in the water resources management depends on skilled professionals, who are involved with the economists, jurists, sociologists, environmentalists, administrators, engineers, hydrologists, hydrogeologists, chemists, biologists, and ecologists; as well as (5) research and development in science and technology are extremely important which help to investigate, to clarify, and to determine solutions of various problems that are related with the technical, economic, and institutional issues on a regional, national, and international scale [LOUCKS 2000; MARIOLAKOS 2007; PAHL-WOSTL *et al.* 2008]. Therefore, the water resources development and water resources management highlighted several domains that have a correlation with the sustainable development approach, namely the water policy, the law and regulation, the sustainable approach, and the water pollution. These domains are used in this study to determine the model of water contamination through sustainable development approach in the river basin management.

## MATERIALS AND METHODS

### STUDY AREA

The Malacca River basin have a catchment area covers approximately 670 km$^2$ together with the Malacca River which is 80 km long flowing across the Alor Gajah district and Melaka Tengah district (Fig. 1). Along the river, there is a reservoir named Durian Tunggal Reservoir, with a catchment of 20 km$^2$, which plays an important role in supplying water to residents in the region. The Malacca state experienced equatorial climate throughout the year, where the annual temperature is between 26 and 30°C; with an average daily mean of 31°C. The minimum annual temperature is between 23 and 27°C and the maximum annual temperature is between 28 and 32°C [WWO 2017]. Then, the average annual relative humidity is between 69 to 84%, with an average annual rainfall of about 195 cm

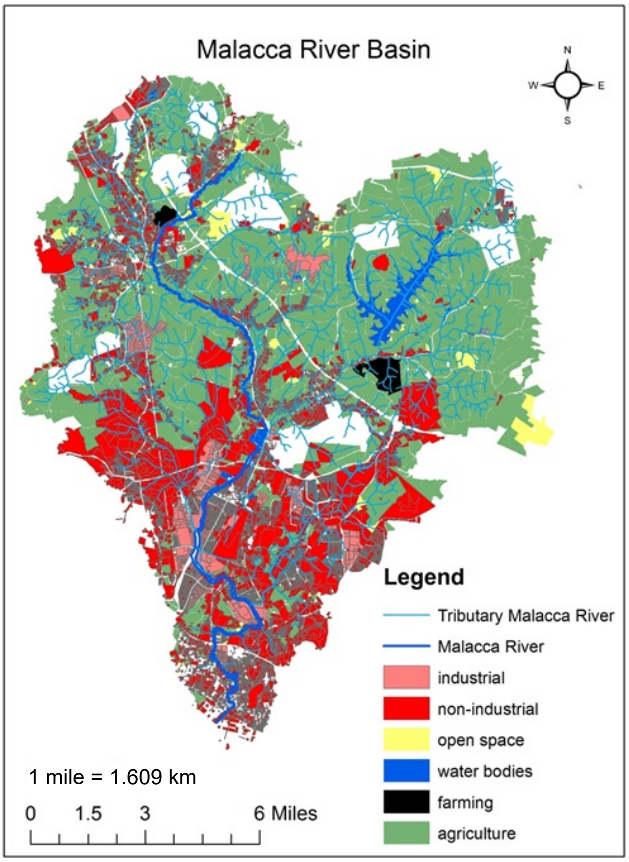


Fig. 1. The study area of Malacca River basin; source: own elaboration

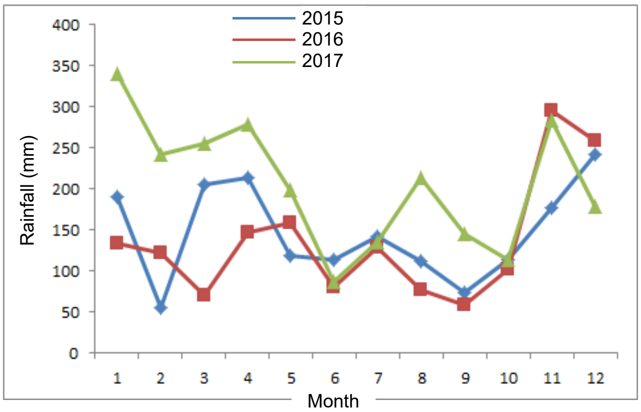


Fig. 2. Monthly rainfall (mm) in Malacca River basin for 2015, 2016, and 2017; source: own study

[WWO 2017] (Fig. 2). In other words, the average of water discharge in the Malacca River is approximately 50 $m^3 \cdot s^{-1}$ during dry season, and increase doubled with approximately 70 $m^3 \cdot s^{-1}$ [DID 2018]. Therefore, a majority of the Malacca residents will experience sunshine during the day and rainfall in the evening when the monsoon wind period arrives. Meanwhile, the increasing population growth has led to rapid urbanisation development in the Malacca state, where most of the residential areas are concentrated in the city which extends towards the west, east and north for 20 km. Apart from economic growth and social relationship, the local residents also face the impact of water pollution in the Malacca River.

## DATA DESCRIPTION AND SURVEY QUESTIONNAIRE

This study applied a quantitative approach, using survey questionnaires. The questionnaire is divided into two sections, namely section A covers demographic details and section B covers the water resources in the Malacca River. Based on the literature review and current issues that have occurred in the Malacca River basin, six domains were identified that were involved with the Malacca River water quality, anthropogenic activities, river water pollution, land-water ecosystem, sustainable, as well as policy-law-regulation. For instance, anthropogenic activities such as industrial, residential and commercial, as well as agricultural are subjected to cause environmental degradation through water pollution in Malacca River [DANESHMAND *et al*. 2011; HUA *et al.* 2016; ROSLI *et al.* 2015]. This circumstance had indirectly reduced the fishing profits and affects the fisherman financial economic activities due to the death of fishes species [DANESHMAND *et al*. 2011; HUA *et al.* 2016; ROSLI *et al.* 2015]. Hence, propose sub-domains of sustainability as well as law, regulation and policy could protect and sustain the river water as nature resources for ecosystem in Malacca River basin. Next, a total of 24 items were used based on the six domains. The questionnaire used 5 categories of scale measurement from 1 to 5, where 1 indicates strongly disagree and 5 indicates strongly agree. This questionnaire will be answered by the local residents, especially the people who are living within the Malacca River basin.

## PARTICIPANTS

Data was collected using qualitative survey from 400 local residents in the Malacca state. In other words, the questionnaire is distributed randomly and only analysed for those who send back the question survey. Based on the respondent's demographic profile, majority of the local residents who took part in the survey and who responded with information are males with 231 people (57.75%), followed by females with 169 people (42.25%). Their ages ranging from 31 to 40 ($n$ = 184, 46%), 41 to 50 ($n$ = 142, 35.5%), and 21 to 30 ($n$ = 74, 18.5%). In terms of ethnicity, 226 of them are Malays (56.5%), 102 are Chinese (25.5%), and 72 are Indians (17.75%). Most of the respondents have lived in the city for 4 years ($n$ = 193, 48.25%), 5 years ($n$ = 137, 34.25%), and 3 years ($n$ = 70, 17.5%), with the majority of 212 people (53%) working in government sector, followed by 107 people (26.75%) in the private sector, and 81 people (20.25%) who are self-employed. Lastly, from an education perspective, about 195 respondents (48.75%) graduated from university, followed by 119 respondents (29.75%) who have studied until secondary school, and 86 respondents (21.5%) who have completed primary school.

## DATA ANALYSIS

Six domains have been identified for this study to produce a structural equation model (SEM), namely the anthropogenic activities, viz; the river water pollution, the land and water ecosystem, the water law-regulation-policy,

**Table 1.** Validity and reliability of variables in model

| Latent variable | Indicator | Convergent validity | | Reliability | | $R^2$ |
|---|---|---|---|---|---|---|
| | | loading | average variance extracted | composite reliability | Cronbach's alpha | |
| AA | A1 | 0.842 | 0.6923 | 0.8999 | 0.8514 | 0.000 |
| | A2 | 0.782 | | | | |
| | A3 | 0.863 | | | | |
| | A4 | 0.839 | | | | |
| LRP | B1 | 0.769 | 0.5802 | 0.8463 | 0.7567 | 0.781 |
| | B2 | 0.809 | | | | |
| | B3 | 0.684 | | | | |
| | B4 | 0.779 | | | | |
| LWE | C1 | 0.849 | 0.5845 | 0.8485 | 0.7639 | 0.735 |
| | C2 | 0.729 | | | | |
| | C3 | 0.758 | | | | |
| | C4 | 0.714 | | | | |
| MR | D1 | 0.593 | 0.5398 | 0.8224 | 0.7165 | 0.769 |
| | D2 | 0.739 | | | | |
| | D3 | 0.777 | | | | |
| | D4 | 0.811 | | | | |
| RWP | E1 | 0.787 | 0.6587 | 0.8852 | 0.8277 | 0.748 |
| | E2 | 0.843 | | | | |
| | E3 | 0.801 | | | | |
| | E4 | 0.814 | | | | |
| S | F1 | 0.857 | 0.7379 | 0.9184 | 0.8815 | 0.812 |
| | F2 | 0.888 | | | | |
| | F3 | 0.811 | | | | |
| | F4 | 0.877 | | | | |

Explanations: AA = anthropogenic activities; LRP = law, regulation and policy; LWE = land and water ecosystem; MR = the Malacca River; RWP = river water pollution; S = sustainability; A1 = industrial, A2 = residential, A3 = commercial, A4 = agricultural; B1 = green technology program, B2 = no plastic program, B3 = recycle program, B4 = education program; C1 = habitat, C2 = shelter, C3 = food supply, C4 = freshwater; D1 = soil structure, D2 = erosion and sedimentation, D3 = floods, D4 = landslide; E1 = poisoning, E2 = disease spread, E3 = toxic, E4 = physico-chemical and biological pollution; F1 = responsibility, F2 = respective, F3 = attitude, F4 = adaption of religious education.
Source: own study.

the sustainable approach, and the Malacca River (Tab. 1). To evaluate and test the model, the partial least square-structural equation model (PLS-SEM) technique is used for the analysis. SMART PLS version 2.0 software was performed to develop the relationship within the domains of the model. Two stages will be involved in PLS-SEM, which is (1) validity (which refers to construct validity and discriminant validity), and (2) reliability (including the composite reliability and Cronbach's alpha internal consistency reliability); as well as (3) the relationship among the domains is identified. Subsequently, the model is determined and reported.

## RESULTS

### VALIDITY AND RELIABILITY OF THE VARIABLES ANALYSIS

The validity and reliability of variables (which refer to indicators) in the domains are required for examination to determine the existence of relationship within the variables (Fig. 3). This is because the six domains that are generated in the model should be valid and reliable, which are important to represent the indicators or instrument items. In other words, the PLS-SEM analysis explains that the six domains referred to as latent variables were represented by their indicators in the particular model that was produced. The validity of the variables can be achieved when (1) the loadings of each individual variable are more than 0.5; and (2) the average variance extracted (AVE) is greater than 0.5 [HAIR *et al.* 2016]. Meanwhile, the reliability of the variable is achieved when (1) the Cronbach's alpha value is greater than 0.7; as well as (2) the composite reliability value is more than 0.7 [HAIR *et al.* 2016]. The results for the six latent variables are achieved for both validity and reliability to develop the model, which can be shown in Table 1.

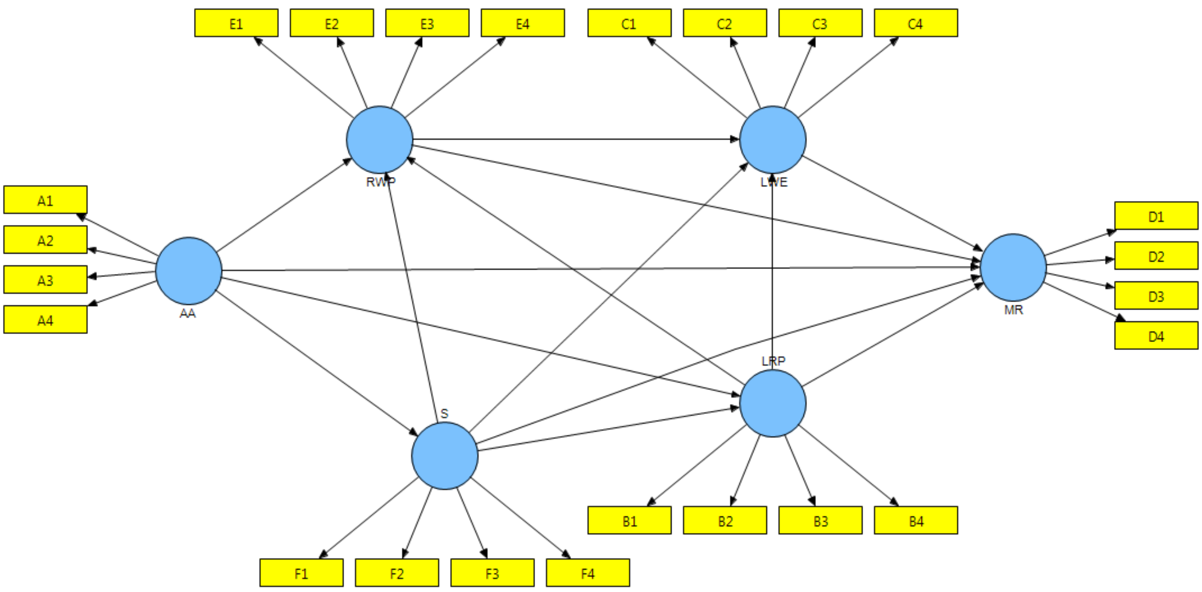


Fig. 3. The 24 indicators of six domains in the model; explanations as in Tab. 1; source: own study

Before the final model is determined, the discriminant validity is required for processing to avoid any overlapping of independent variable that exists in the model. In other words, the overlapping concept can occur when multi-collinearity happens because of the extremely strong inter-correlation between variables in the model [BRYNE 2010]. Inter-correlations can be achieved when the variables are smaller than 0.9 [BRYNE 2010]. Table 2 indicates that all variables of the inter-correlation coefficients are less than 0.9, which are free from multi-collinearity issues as well as the discriminant validity of the variables for the model is achieved.

**Table 2.** Inter-correlation among the variables in model

| Latent variables correlation | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| 1 | anthropogenic activities | 1.0000 | | | | | |
| 2 | law, regulation and policy | 0.5435 | 1.0000 | | | | |
| 3 | land and water ecosystem | 0.7316 | 0.5500 | 1.0000 | | | |
| 4 | the Malacca River | 0.4324 | 0.6811 | 0.4764 | 1.0000 | | |
| 5 | river water pollution | 0.7473 | 0.5593 | 0.6823 | 0.5150 | 1.0000 | |
| 6 | sustainability | 0.7683 | 0.5971 | 0.6287 | 0.5242 | 0.8185 | 1.0000 |

Source: own study.

## THE FINAL MODEL

According to HAIR *et al.* [2016], the SMART PLS software enables researchers to perform an inter-relationship among the latent variables with multiple indicators for analysis with accuracy and effectiveness. In other words, the SMART PLS software enables researchers to carry out multivariate analysis in producing multiple equations, which includes regression, factorisation, as well as the analysis of variance.

The final model as shown in Figure 4 consists of sustainable development of water resource management with the six domain factors. Since the quality and quantity of water resources are important to living being, therefore, water contamination in the Malacca River requires preservation and conservation to sustain the water supply for human consumption and the ecosystem. The Malacca River is considered to be directly influenced by three core factors, namely the anthropogenic activities, the river water pollution, as well as the land and water ecosystem; which have also been indirectly influenced by the water law-regulation-policy and the sustainable approach. Table 3 indicates the factors which have contributed 76.9% of sustainable development to the water resources management ($R^2 = 0.769$).

As described previously, the Malacca River is influenced by the five core factors, which indicated that the main factor is water law-regulation-policy ($\beta$ = 0.546, $p < 0.001$), followed by anthropogenic activities ($\beta$ = 0.145,

**Table 3.** *T*-statistic and standardized regression weight ($\beta$) of the relationship among variables in model

| Hypothesis | Relationships (IV > DV) | *T*-statistics value | Standardized regression weight ($\beta$) |
|---|---|---|---|
| H1 | AA > MR | 3.2808**** | 0.145 |
| H2 | LRP > MR | 16.1604**** | 0.546 |
| H3 | LWE > MR | 2.8865*** | 0.105 |
| H4 | RWP > MR | 3.3601**** | 0.142 |
| H5 | S > MR | 2.3723** | 0.127 |
| H6 | AA > RWP | 7.6549**** | 0.273 |
| H7 | LRP > RWP | 3.1294*** | 0.073 |
| H8 | S > RWP | 18.8807**** | 0.565 |
| H9 | LRP > LWE | 6.8609**** | 0.223 |
| H10 | RWP > LWE | 10.4065**** | 0.460 |
| H11 | S > LWE | 2.7418*** | 0.119 |
| H12 | AA > LRP | 4.9860**** | 0.211 |
| H13 | S > LRP | 10.7532**** | 0.436 |
| H14 | AA > S | 53.8585**** | 0.768 |

Explanations: AA, LRP, LWE, MR, RWP, S as in Tab. 1; IV = independent variable; DV = dependent variable; ** = significant at $p < 0.5$; *** = significant at $p < 0.01$; **** = significant at $p < 0.001$; all variables are supported.
Source: own study.

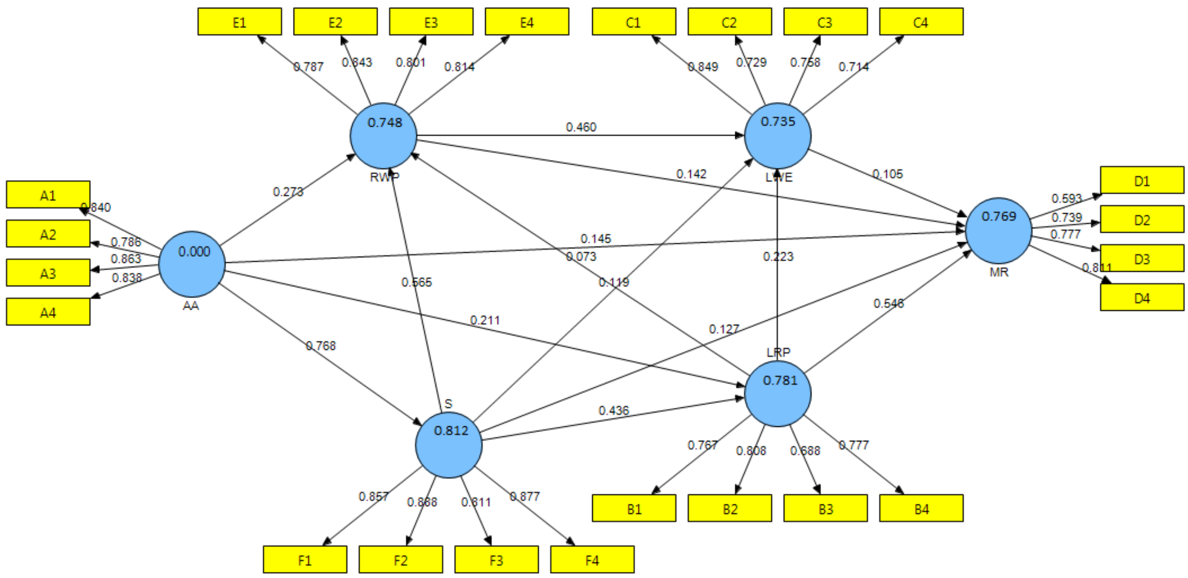


Fig. 4. The model of sustainable development of water resources management; explanations as in Tab. 1; source: own study

$p < 0.001$), river water pollution ($\beta = 0.142$, $p < 0.001$), land and water ecosystem ($\beta = 0.105$, $p < 0.01$), as well as sustainable approach ($\beta = 0.127$, $p < 0.5$). In other words, one positive unit input of anthropogenic activities would cause the chance for 0.546 unit to increase in the Malacca River. Therefore, the implication of water law-regulation-policy and the sustainable approach applied to river water pollution and land and water ecosystem would maximised the water resources in the Malacca River by 76.9% ($R^2$ = 0.769).

Meanwhile, a total of 74.8% of river water pollution in the Malacca River are significantly influenced by sustainable approach ($\beta = 0.565$, $p < 0.001$), anthropogenic activities ($\beta = 0.273$, $p < 0.001$), and water law-regulation-policy ($\beta = 0.073$, $p < 0.01$). Therefore, to improve water resources, a sustainable approach should come first and be implemented into anthropogenic activities before water law-regulation-policy are applied to preserve the water quality in Malacca River.

Thirdly, a total of 73.5% of land and water ecosystem surrounding the Malacca River basin is influenced by river water pollution ($\beta = 0.460$, $p < 0.001$), water law-regulation-policy ($\beta = 0.223$, $p < 0.001$), and sustainable approach ($\beta = 0.119$, $p < 0.01$). Therefore, the results stated that water law-regulation-policy is the main factor to conserve water quality from continuous contamination in the Malacca River. Coupled with a sustainable approach, the health of the land and water ecosystem is able to be maintained and be avoided from any extinction species to happen.

Fourthly, the water law-regulation-policy of 78.1% is influenced by a sustainable approach ($\beta = 0.436$, $p < 0.001$) and anthropogenic activities ($\beta = 0.211$, $p < 0.001$). Lastly, a sustainable approach with 81.2% is influenced by anthropogenic activities ($\beta = 0.768$, $p < 0.001$). Both water law-regulation-policy and sustainable approach play an important role to increase the quality and quantity of water resources in the Malacca River when the factors are applied to anthropogenic activities.

The sub-model of sustainable development of water resource management is presented in Table 4. These sub-models are the basics of the water resources management model in the Malacca River basin.

**Table 4.** Sub-models of the Malacca River water management model

| | Sub-model regression model | $R^2$ |
|---|---|---|
| 1 | MR = 0.367AA + 0.811RWP + 0.753LWE | 0.772 |
| 2 | MR = 0.330AA + 0.422S – 0.396RWP – 0.364LWE | 0.862 |
| 3 | MR = 0.391AA + 0.376LRP – 0.487RWP – 0.316LWE | 0.837 |
| 4 | MR = 0.442AA + 0.431S + 0.357LRP – 0.582RWP – 0.495LWE | 0.910 |

Explanations: AA, LRP, LWE, MR, RWP, S as in Tab. 1; all variables have strong effect.
Source: own study.

## DISCUSSION

Three criteria had emerged from the sub-model in this study, which can be used to define the sustainable development of water resource management in the Malacca River basin. Firstly, anthropogenic activities through industrial, urbanisation, as well as agriculture would directly benefit the quality of human life, but indirectly could cause degradation to the quality of the river water through continuous contamination. This situation occurs in the Malacca River basin, which is suspected to happen after population centralisation and the rapid urbanisation taking place in the city. Without realising, that river water pollution had caused the land and water ecosystem species to extinct, human health has also been detected to decline [HUA, MARSUKI 2014]. Therefore, if this is not prevented, the environmental nature will experience "destruction".

Since the water pollution of the Malacca River basin is connected with anthropogenic activities, therefore, sustainable approach and water law-regulation-policy is considered the best alternative to cope with the continuous contamination. Both factors are referred to as second and third criteria in the sub-model of this current study. In other words, applied sustainable approach is involved with the "Green Technology Programme", "No Plastic Product Programme", "Recycle Programme", "Love Our River Programme", as well as education programme, which plays an important role to at least, reduce continuous contamination towards water quality in the river. Based on a study conducted by HUA [2015a], who indicated that majority of the local residents who joined the programme positively agreed with the action taken by the Malacca State Government that any products or equipment involving plastics are prohibited from daily use; as well as to increase awareness on the danger of toxic waste that affects the river water quality and to practice using biodegradable or paper bags. Moreover, the water law-regulation-policy is likely to be involved with "Water Acts 1920", "Sewage Service Acts 1993", "Sewage and Industrial Effluents 2000", "Production Waste Action Plan" with "Zero Waste Action Plan", and "Toxic Reduction Plan". Also, the "Habitat Protection Action Plan" in Malacca by the State Government not only supports the sustainable programme to achieve the goal, but also to protect the environment by controlling the irresponsible attitude that may bring harm to the river water quality. In this case, other than penalty in the form of money, whipping and jail, the local resident suggested cleaning the river as another alternative to awaken their wrong actions that lead to a negative impact on river pollution [HUA 2015b]. Therefore, the sustainable approach and water law-regulation-policy should be implemented and practice simultaneously to conserve and preserve the river water quality from continuous contamination. Moreover, it is the human being who is responsible to reduce the river pollution and protect the environment from any harm and destruction on the ecosystem.

## CONCLUSIONS

This study developed a model for the sustainable development of water resources management in the Malacca River basin. Researchers are able to use this information to investigate and to identify unanswered problems or questions regarding the literature as well as determine future research directions concerning water resources management. This study helps environmentalists, administrators, and ecologists to better understand the river water and the factors that are related to it.

The strength of this study suggests for an earlier approach of the model involved with water resources management and sustainable development. Nevertheless, the findings of this study are limited to the characteristic of the Malacca River basin, and further research can be conducted in other locations and fields of studies in order to provide a greater picture of the sustainable development of water resources management.

**ACKNOWLEDGEMENTS**

The authors acknowledge the support and encouragement of the staff from Faculty of Environmental Studies, Universiti Putra Malaysia, Malaysia.

## REFERENCES

BARAKAT A., EL BAGHDADI M., MEDDAH R., RAIS J., NADEM S., AFDALI M. 2013. Evaluation of water quality in open channels flowing through Beni-Mellal City (Morocco). Journal of Water and Land Development. No. 19 p. 3–11.

BRYNE B.M. 2010. Structural equation modeling with SMART PLS: Basic concepts, applications, and programming. 2nd ed. New York. Routledge, Taylor and Francis Group. ISBN 9780203807644 pp. 432.

CUKROV N., TEPIC N., OMANOVIC D., LOJEN S., BURA-NAKIC E., VOJVODIC V., PIZETA I. 2012. Qualitative interpretation of physico-chemical and isotopic parameters in the Krka River (Croatia) assessed by multivariate statistical analysis. International Journal of Environmental Analytical Chemistry. Vol. 92. Iss. 10 p. 1187–1199.

DANESHMAND S., HUAT B.B., MOAYEDI H., ALI T.A.M. 2011. Study on water quality parameters of Linggi and Melaka Rivers catchments in Malaysia. Engineering Journal. Vol. 15. Iss. 4 p. 41–52.

DID 2018. The average discharge of Melaka River [online]. Kuala Lumpur. Department of Irrigation and Drainage. Ministry of Water, Land and Natural Resources. [Access 15.10.2018]. Available at: https://www.water.gov.my/index.php/pages/view/663

HAIR J.F., HULT G.T.M., RINGLE C.M., SARSTEDT M. 2016. A primer on partial least square structural equation modeling (PLS-SEM). 2nd ed. Thousand Oaks. Sage. ISBN 9781483377445 pp. 390.

HOSSAIN N., BAHAUDDIN K. M. 2013. Integrated water resource management for mega city: a case study of Dhaka city, Bangladesh. Journal of Water and Land Development. No. 19 p. 39–45.

HU J., QIAO Y., ZHOU L., LI S. 2012. Spatiotemporal distributions of nutrients in the downstream from Gezhouba Dam in Yangtze River, China. Environmental Science and Pollution Research. Vol. 19. Iss. 7 p. 2849–2859.

HUA A.K. 2015a. An indication of policy study towards water resources in Malacca state: A case study of Malacca River, Malaysia. International Research Journal of Social Sciences. Vol. 4. Iss. 6 p. 15–20.

HUA A.K. 2015b. Law enforcement and water resources of the Malacca River a case study of public perception. International Journal of Scientific Research in Science and Technology. Vol. 3. Iss. 1 p. 111–116.

HUA A.K. 2017. Analytical and detection sources of pollution based environmetric techniques in Malacca River, Malaysia. Applied Ecology and Environmental Research. Vol. 15. Iss. 1 p. 485–499.

HUA A.K., KUSIN F.M., PRAVEENA S. M. 2016. Spatial variation assessment of river water quality using environmetric techniques. Polish Journal of Environmental Studies. Vol. 25. Iss. 6 p. 2411–2421.

HUA A.K., MARSUKI M.Z. 2014. Public perception towards environmental awareness. Case study: Malacca River. International Journal of Academic Research in Environment and Geography. Vol. 1. Iss. 2 p. 53–61.

JAMES P. 2014. Urban sustainability in theory and practice: circles of sustainability. London–New York. Routledge. ISBN 978-1-138-02573-8 pp. 180.

KOPACZ M., TWARDY S. 2012. Gospodarka wodno-ściekowa w zlewni górnego Dunajca na tle przeobrażeń społeczno-strukturalnych i jakości wód powierzchniowych [Water and sewage management in the Upper Dunajec River catchment basin compared to the socio-structural transformations and surface water quality]. Woda-Środowisko-Obszary Wiejskie. T. 12. Z. 3 p. 103–121.

LIU X., YUA X., YU K. 2012. The current situation and sustainable development of water resources in China. Procedia Engineering. Vol. 28 p. 522–526.

LOUCKS D.P. 2000. Sustainable water resources management. Water International. Vol. 25. Iss. 1 p. 3–10.

MANDAL P., UPADHYAY R., HASAN A. 2010. Seasonal and spatial variation of Yamuna River water quality in Delhi, India. Environmental Monitoring and Assessment. Vol. 170. Iss. 1 p. 661–670.

MARIOLAKOS I. 2007. Water resources management in the framework of sustainable development. Desalination. Vol. 213. Iss. 1–3 p. 147–151.

MISHRA S., KUMAR A., SHUKLA P. 2016. Study of water quality in Hindon River using pollution index and environmetrics, India. Desalination and Water Treatment. Vol. 57. Iss. 41 p. 19121–19130.

MOURI G., TAKIZAWA S., OKI T. 2011. Spatial and temporal variation in nutrient parameters in stream water in a rural-urban catchment, Shikoku, Japan: Effects of land cover and human impact. Journal of Environmental Management. Vol. 92. Iss. 7 p. 1837–1848.

MUSTAPHA A., ARIS A.Z., JUAHIR H., RAMLI M.F., KURA N.U. 2013. River water quality assessment using environmentric techniques: Case study of Jakara River Basin. Environmental Science and Pollution Research. Vol. 20. Iss. 8 p. 5630–5644.

NEL J.L., DRIVER A., STRYDOM W.F., MAHERRY A., PETERSEN C., HILL L., ROUX D.J., NIENABER S., VAN DEVENTER H., SWARTZ E., SMITH-ADAO L.B. 2011. Atlas of freshwater ecosystem priority areas in South Africa: Maps to support sustainable development of water resources. Water Research Commission Report. No. TT 500. Iss. 11 pp. 783.

PAHL-WOSTL C., MOSTERT E., TABARA D. 2008. The growing importance of social learning in water resources management and sustainability science. Ecology and Society. Vol. 13. Iss. 1. Art. 24.

PASSET R. 1979. L'économique et le vivant [The economic and the living]. Ser. Traces. Vol. 23. Paris. Payot pp. 287.

REZAEI A., SAYADI M.H. 2015. Long-term evolution of the composition of surface water from the River Gharasoo, Iran: A case study using multivariate statistical techniques. Environmental Geochemistry and Health. Vol. 37. Iss. 2 p. 251–261.

ROSLI S.N., ARIS A.Z., MAJID N.M. 2015. Spatial variation assessment of Malacca River water quality using multivariate statistical analysis. Malaysian Applied Biology. Vol. 44. Iss. 1 p. 13–18.

TIWARI P.C., JOSHI B. 2012. Environmental changes and sustainable development of water resources in the Himalayan headwaters of India. Water Resources Management. Vol. 26. Iss. 4 p. 883–907.

VENKATRAMANAN S., CHUNG S.Y., LEE S.Y., PARK N. 2014. Assessment of river water quality via environmentric multivariate statistical tools and water quality index: A case study of Nakdong River basin, Korea. Carpathian Journal of Earth and Environmental Sciences. Vol. 9 p. 125–132.

WCED 1987. Sustainable development, our common future. The Brundtland Report. World Commission on Environment and Development pp. 383.

WWO 2017. Malacca current weather report [online]. World Weather Online. [Access 15.10.2018]. Available at: https://www.worldweatheronline.com/melaka-weather-averages/melaka/my.aspx

**Ang Kean HUA**

**Model równania strukturalnego zastosowany w zrównoważonym rozwoju gospodarki wodnej**

STRESZCZENIE

Zanieczyszczenie wód rzecznych jest zjawiskiem znanym na całym świecie. Mając na względzie zrównoważony rozwój, podjęto badania, aby sprawdzić model strukturalnego równania w powiązaniu ze zrównoważonym rozwojem i gospodarką wodną w basenie rzeki Malakka w Malezji. Model składa się z sześciu ukrytych elementów (działalność człowieka; prawo, przepisy i polityka; ekosystemy lądowe i wodne; rzeka Malakka; zanieczyszczenie wód rzecznych; trwałość) i 24 jednostek opartych na 400 ankietach, które zostały wypełnione i przesłane przez mieszkańców stanu Malakka. Wybrany obszar badań mieścił się w basenie rzeki Malakka. Wyniki wskazują, że na rzekę Malakka wpływa polityka w zakresie prawa wodnego ($\beta$ = 0,546, $p$ < 0,001), działalność człowieka ($\beta$ = 0,145, $p$ < 0,001), zanieczyszczenie wód rzecznych ($\beta$ = 0,142, $p$ < 0,001), ekosystem lądowy i wodny ($\beta$ = 0,105, $p$ < 0,01), a także podejście zrównoważone ($\beta$ = 0,127, $p$ < 0,5). Stwierdzono, że podejście zrównoważone oraz prawne aspekty dotyczące wody mają bezpośredni wpływ na działalność człowieka, zanieczyszczenie wód rzecznych oraz na ekosystemy lądowe i wodne. Przedstawione badania sugerują rozwijanie modelowego podejścia do zrównoważonego rozwoju gospodarki wodnej.

**Słowa kluczowe:** *basen rzeki Malakka, lokalni mieszkańcy, podejście zrównoważone, prawo i przepisy, woda*