International Journal of Infrastructure Research and Management

Vol. 11 (1), June 2023

ISSN 2811-3608
eISSN 2811-3705
PP 18094/04/2013(033449)

International Journal of Infrastructure Research and Management
Vol. 11 (1), June 2023

Published by
IKRAM Education Sdn. Bhd. *for*
INFRASTRUCTURE UNIVERSITY KUALA LUMPUR

Printed by
Printing Unit
KUMPULAN IKRAM SDN. BHD.

International Journal of Infrastructure Research and Management
Vol. 11 (1), June 2023

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International Journal of Infrastructure Research and Management
Vol. 11 (1), June 2023 pp. 1 - 10

INFLUENCE OF POPULATION DENSITY ON COVID-19 MEDICAL WASTE GENERATION IN SELANGOR AND KUALA LUMPUR

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ABSTRACT

The COVID-19 virus is easily spread, which caused the World Health Organization to announce it as a pandemic. During the COVID-19 pandemic, an enormous amount of Medical Waste was generated throughout the world. The sudden increase in medical waste created an additional challenge in medical waste management, especially in an urban area with a high density of population. This paper presents a study on medical waste generation in high-density population areas, specifically Selangor and Kuala Lumpur, to see the influence of population density on medical waste generation during the COVID-19 pandemic. The medical waste generation rate was estimated using Sangkham's equation based on the number of positive cases reported. The results showed that the continuous increase in the number of confirmed COVID-19 cases has increased the number of the medical waste generation rate (Mw). Generally, the trends of Mw for both Selangor and Kuala Lumpur have a similar pattern. Even though Selangor and Kuala Lumpur have similar population densities, Selangor exhibited a much higher Mw rate compared to Kuala Lumpur. The Mw peak during the COVID-19 pandemic for Selangor is 569% higher compared to the value of Mw before the pandemic. This is a highly significant increase compared to the pre-COVID-19 Mw. For Kuala Lumpur, the intra COVID-19 value is 94% higher than the pre-COVID-19 threshold. This is almost double the pre-COVID-19 value but still five times smaller than the Selangor intra-COVID-19 value. Other than that, the Mw dipped under the threshold line (pre-COVID-19 Mw) at the end of the study period. This may even decrease and be maintained below pre-COVID-19 Mw values for the first time in months. According to the findings, it can be concluded that the population density of the area is not a contribution factor to the increase of COVID-19 cases and at the same time, it is not a controlling factor to the COVID-19 medical waste generation. In this case, the medical waste generation rate cannot be predicted based on the population density of the area.

Keywords:
COVID-19, Hazardous Waste, Medical Waste, Generation rate, Population density

INTRODUCTION

At the end of year 2019, the world was shocked by the outbreak of a new type of coronavirus (SARS-CoV-2) known as COVID-19. This virus causes severe respiratory illnesses and has killed millions of lives worldwide. Globally, as of 22 November 2022, there were 635,229,101 confirmed cases of COVID-19, including 6,602,552 deaths, reported to the World Health Organization (WHO). The virus is easily transmitted through direct droplet transmissions such as coughing and sneezing (Lepelletier et al., 2020). Besides the omnipotence of the virus, COVID-19 is also responsible for the large increase of medical waste (Mw) and single-use plastics from personal protective equipment (PPE) and packaging (e.g. face masks, gloves, clothes, goggles, and sanitizer/disinfectant containers). The waste is generated from the countermeasures taken by each government in preventing and reducing the infection of the COVID-19 virus. Generally, COVID-19 waste mainly consists of medical waste (Mw) (Dharmaraj et al., 2021). The term "medical waste" refers to the waste originating from hospitals, clinics and health care facilities and can be categorized into five main classes: medical, radioactive, chemical, general wastes and containers (DOE, 2009).

According to a report by WHO, "Global analysis of healthcare waste in the context of COVID-19: status, impacts and recommendations", vaccination alone has generated 144,000 tonnes of additional waste in the form of syringes, needles, and safety boxes. This amount is not included the

waste generated from the treatment of COVID-19 patients. The large amount of COVID-19 medical waste brings a tremendous burden to the environment and may cause serious public health issues if not properly managed. This creates an additional challenge in medical waste management, particularly in developing countries.

Currently in Malaysia, there are 144 public hospitals with a total of 42,000 beds and 240 private hospitals with a total of 16,000 beds, which produced Mw of around 33,000 tonnes/annually or 90 tonnes/day with approximately 80% of non-pathogenic waste whereas 15% is pathogenic waste and chemical wastes. Pharmaceutical, sharp, and other waste account for 3%, 1% and 1%, respectively (Ambali et al., 2013). According to Minoglou et al. (2017), the average pre-COVID-19 Mw rate generation in developing and developed countries is 4.2 kg/bed/day and 2.56 kg/bed/day respectively. In Malaysia, the pre-COVID-19 generation rate of medical waste is 1.9 kg/bed/day which is lower compared to the global average reported. There is lower Mw generation rate recorded in a city such as Penang where the generation rate of pre-COVID-19 medical waste with only 0.4 -1.0 kg/bed/day, which is much lower than the national value (Agamuthu & Barasarathi, 2020; Rabeie, 2012).

However, due to the highly transmissive and lethal nature of the COVID-19 disease, medical waste skyrocketed to meet the demand for prevention and treatment of the disease. Any type of medical waste produced from COVID-19 treatments, including materials such as facemasks, medical gowns and medical gloves, is considered pathogenic Mw. According to the World Health Organization (2018), pathogenic Mw includes materials that contain dangerous microbes that can readily transmit to other individuals and hospital staff, if not managed and properly disposed of. These human coronaviruses may also survive up to nine days on inorganic hard surfaces which include plastic, glass, or metal, as shown in research by Kampf et al. (2020).

Currently, the medical waste management (MWM) relating to COVID-19 infections follows the established regulations of MWM detailed by the Federal Government and the DOE. The disposal of Mw is regulated by the Schedule of Waste Regulation (2005), the Environmental Quality Act (1974) and the Ministry of Health's (MOH) standard operating procedures. Malaysia is presently implementing the Environmental Quality Act 1974, with some of the latest modifications. However, due to the high medical waste generation, there would be a threat of unsafe disposal of the waste, especially in highly developing countries with limited treatment facilities (Sangkham, 2020). At the time this study was conducted, in January 2022, Malaysia had recorded a total of 1,113,272 COVID-19 cases and 9,024 deaths. Moreover, there is an exponential increment of cases as a result of the emergence of the highly transmissive delta variant of the virus. Thus, medical waste generation was likely to fluctuate based on these factors. Therefore, the understanding of Mw generation is important to ensure efficient management and disposal of Mw during the pandemic situation can be properly implemented.

In this research, a mathematical equation called Sangkham's equation is used for predicting and simulating the daily COVID-19 Mw generation rate in Malaysian urban areas. Through this method, the Mw generation rates are calculated based on the number of COVID-19 cases. Medical waste has a substantial influence on humans and nature; hence, this study sought to investigate the Mw generated from the most highly populated areas of the states of Peninsular Malaysia, in particular Selangor and Kuala Lumpur. The information on the medical waste generated is useful for the authorities to plan good medical waste management to prevent unsafe disposal, which in turn may increase the risk of spreading of the virus. Other than that, the data obtained from this study also can be used as a baseline if a similar pandemic situation occurs in the future.

METHODOLOGY

Location of study

The focus of this study is to determine the amount of medical waste generated in Kuala Lumpur and Selangor as shown in Figure 1. According to the Department of Statistics Malaysia (DOS) (2018), the population of Selangor is 6,448,400, the largest in Malaysia. It has the biggest economy in Malaysia, therefore, having the most population movement during the pandemic in its 8,104 km^2 of area (DOSM, 2007).

Figure 1: The Map show the location of Selangor and Kuala Lumpur within Peninsular Malaysia (Google Map, January 2022).

There are only four other states that have more than one official city status area besides Selangor. Meanwhile, Kuala Lumpur is the capital and largest city of Malaysia. The Greater Kuala Lumpur metropolitan area is one of the fastest growing regions in Southeast Asia with 7.564 million population in 2018 in a 2,243.27 km^2 wide area (UN DESA, 2018; DOSM, 2011). Kuala Lumpur is the political, economic and cultural centre of Malaysia. These two states have been chosen because they are two of the most urban areas in Malaysia with some of the highest numbers of COVID-19 cases by state.

Data Collection

The number of daily cases data for each state was gathered from government websites (https://covidnow.moh.gov.my/cases/ and https://covid-19.moh.gov.my/terkini/) for a duration of one year, from October 2020 until October 2021 (MOH, 2020).

COVID-19 Medical Waste Generation Prediction

There are two Mw generation rates in this study: MWGR and Mw. MWGR is the generation rate in kg/bed/day, while Mw is the generation rate in tonnes/day. In this study, a given MWGR will be used as a fixed variable in the equation in order to obtain the Mw.

Using Sangkham's mathematical formula (2020), the value of Mw generated was calculated by multiplying the medical waste generation rate (MWGR) value in kg/bed/day with the daily number of confirmed cases. This results in the waste generation rate in kg/day. To convert from kg/day to tonne/day, the previous value will be divided by 1,000. From the current body of knowledge, there is insufficient literature regarding MWGR in urban areas of Malaysia, therefore the value of 3.95kg/bed/day reported by Abu-Qdais et al. (2020) was adopted in this study.

The 3.95 kg/bed/day value is a relatively high value compared to the pre-COVID-19 values of high-income and low-income countries alike (WHO, 2020), and Abu-Qdais' MWGR was formulated by issuing a survey to the hospital management in a Jordanian hospital. Therefore, this value was related to the number of hospitalized COVID-19 patients, and not including the un-hospitalized cases. However, the MWGR value was still used by Sangkham because the population density and development level of the Jordanian area is similar to that of Selangor and Kuala Lumpur. In addition, this value is higher than the pre-COVID-19 values mentioned above. Therefore, it is suitable to use this value to differentiate this study from pre-COVID-19 medical waste generation studies. These are the considerations that have been made by Sangkham et al. in order to assume this value to be used in this Malaysian medical waste generation study.

The following is Sangkham's (2020) equation that was used to estimate the medical waste generated from the COVID-19 cases (Equation 3-1; Table 1 and Table 2). The medical waste, Mw was calculated in tonnes/day:

$$Mw = \frac{N\ DC \times MWGR}{1000} \qquad (3\text{-}1)$$

Where NDC is the number of daily COVID-19 cases, MWGR represents medical waste generation rate in kg/bed/day. This Mw accounts for all the waste produced from diagnosis, treatment and testing sample of COVID-19 patients. This investigation depends on the reliability of COVID-19 confirmed case statistics and the information made publicly available.

The data obtained were plotted into two graphs of the medical waste generation in tonnes/day against time in days and weeks. A weekly moving average was calculated from the daily data using Microsoft Excel. The weekly moving average was then used to calculate the monthly moving average. The monthly moving average was used to create a graph superimposed on the weekly graph.

RESULTS AND DISCUSSION

COVID-19 Medical Waste Generation Rate Estimation

Table 1 shows the descriptive analysis of minimum, maximum and mean value of the daily Mw generation in Selangor and Kuala Lumpur from October 2020 to October 2021. This result was correlated with the number of daily confirmed cases in each state presented in Figure 2. It can be seen that the Mw generation rate in Selangor ranged from 0.05135 tonnes/day to 34.7284 tonnes/day while Kuala Lumpur recorded 0.00395 tonnes/day to 11.376 tonnes/day. The mean averages of Mw generation in Selangor and Kuala Lumpur are 7.11385 tonnes/day and 1.90002 tonnes/day respectively. Interestingly, even though Selangor and Kuala Lumpur have similar population densities, the Mw generated in Selangor is 3.7 times higher than in Kuala Lumpur. The result demonstrated that population density is not the determining factor that influenced the number of confirmed cases which also reflected the amount of Mw generated in the respective state. Similar findings were also reported by Al-Omran et al., (2021) and ADB (2020).

Table 1: The minimum, maximum, mean and standard deviation of the daily Mw generation in Selangor and Kuala Lumpur from October 2020 to October 2021.

	Minimum	Maximum	Mean	Standard Deviation
Selangor	0.05135	34.7284	7.11385	7.773488
Kuala Lumpur	0.00395	11.376	1.90002	2.16488

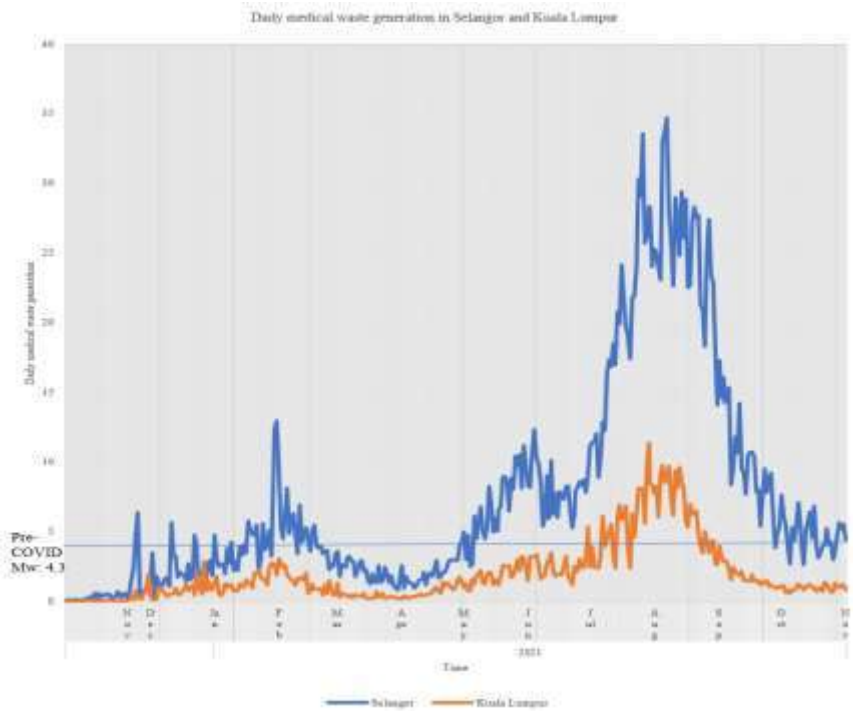

Figure 2: Graph of daily medical waste generation rate in Selangor and Kuala Lumpur from October 2020 to October 2021.
(Source: MOH, 2020)

The Trends of COVID-19 Medical Waste Generated in Selangor and Kuala Lumpur

The COVID-19 infections generated a huge amount of medical waste within the analysed period. The trend of medical waste generated can be seen in Figure 3. Generally, the trends and fluctuations for both Selangor and Kuala Lumpur follow approximately the same shape, with the rate for Kuala Lumpur being lower than Selangor. The graph shows a fluctuation of Mw generation in an upward trend from October 2020 until July 2021 as the COVID-19 cases in Malaysia had been rising from the start of the pandemic.

There are two prominent peaks of Mw in February and August 2021 as can be seen in Figure 3. The second peak (34.7284 tonnes/day for Selangor and 11.376 for Kuala Lumpur) shows eight and two times increase from the pre-COVID-19 Mw generation rate. From July until August 2021, the rates had reached higher than 20.0 tonnes/day for Selangor.

According to the clusters list (MOH,2020), Selangor and Kuala Lumpur had a ratio of 2.3:1 for the number of clusters that emerged inside the states: 1310 and 559 clusters respectively. Although the number of clusters found in Kuala Lumpur is half that in Selangor, the difference between their Mw generated do not follow the same ratio. This difference is much higher than the ratio. This shows that for every cluster in Selangor, the Mw generated is higher than the Mw generated for one cluster in Kuala Lumpur. The weekly and monthly moving averages of the daily Mw were calculated and shown in Figure 3. The averages were calculated to better portray the trends in Mw.

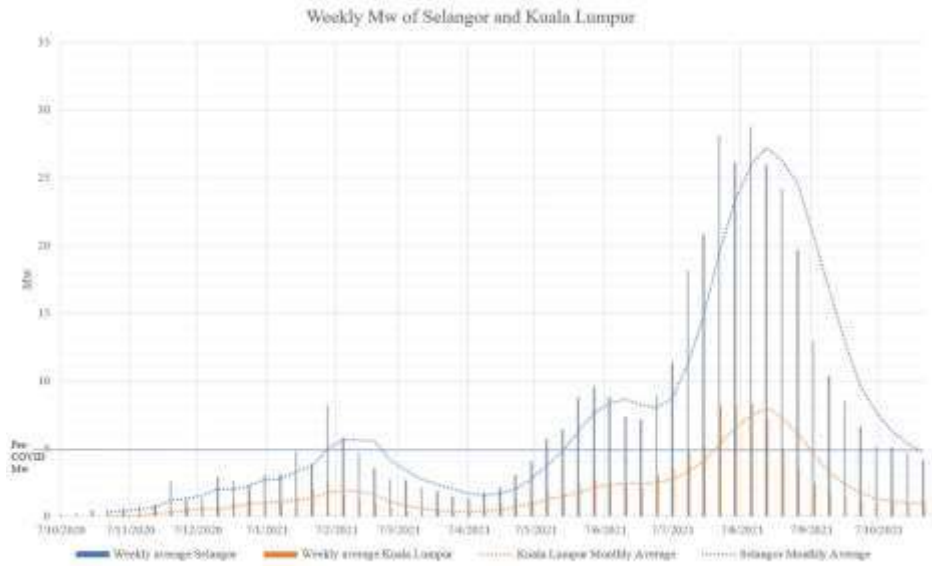

Figure 3: Weekly and monthly average medical waste generation rate in Selangor and Kuala Lumpur from October 2020 to October 2021.

The blue columns represent the weekly Mw for Selangor, while the orange column represents the weekly Mw values for Kuala Lumpur. The blue and orange lines represent the rolling 30 days moving average of the Mw values in both states. The blue threshold line is the value of medical waste generation rate estimated before the COVID-19 pandemic. The threshold value is based on the Mw in Selangor (Razali & Ishak, 2009).

As can be seen in Figure 3, the trend moved generally upwards as the COVID-19 cases in Malaysia had been rising from the start of the pandemic, save for the commencement of the first lockdown when the cases decreased. The general trends and fluctuations for both Selangor and Kuala

Lumpur followed approximately the same shape, where the rate for Kuala Lumpur was lower than Selangor. In 2021, the rates reached higher than 20.0 tonnes/day.

To understand the trends of Mw based on the value of Mw before COVID-19, the blue threshold line in Figure 3 represents the pre-COVID-19 Mw. The Mw peak during COVID-19 for Selangor is 569% higher than the value of Mw before COVID-19 (from 4.3 tonnes/day to 28.7724 tonnes/day). This is a highly significant increase compared to the pre-COVID-19 Mw. For Kuala Lumpur, the intra-COVID-19 value is 94% higher than the pre-COVID-19 threshold (from 4.3 tonnes/day to 8.34522 tonnes/day). This is almost double the pre-COVID-19 value but still 5 times smaller than the Selangor intra-COVID-19 value.

To discuss the Mw fluctuations, the movement control orders (MCOs) or lockdowns mandated by the Malaysian Government must be included in the discussion, as the Mw estimation in this study is directly correlated with the number of COVID-19 cases. From the start of the pandemic to January 2021 and March to May 2021, the intra-COVID-19 values are below the pre-COVID-19 threshold line. The first duration matches the duration of the conditional movement control order (MCO) and recovery phase, meaning the Mw was low from the start of the pandemic up until the MCO reached the conditional and recovery stages on 1 May 2020, until 11 January 2021 (Bernama, 2020; Rodzi, 2021). The low generation rate (0.05 - 5.00 tonnes/day for Selangor and 0.05 - 1.50 tonnes/day for Kuala Lumpur) in the beginning is closely related to the movement control order (MCO) commencement. This means that the COVID-19 infections were not rampant yet up until the second MCO was mandated.

From January to March 2021 and May to October 2021 the intra-COVID-19 values are above the threshold line. However, it seems as though the Mw after October decreased to below the threshold for the first time in months. If the COVID-19 hospitalizations and quarantined cases decreased after October and cases caused by further COVID-19 variants turned out to cause less symptomatic, the Mw may even decrease and be maintained below pre-COVID-19 values from the time of writing (The Economist Newspaper, 2022). Although, the more long-term future Mw will depend on government and consumer efforts for the reduction of the use of non-reusable test kits and a shift towards relatively more reusable diagnostic devices.

From 3 May 2021 until 15 June 2021, the Malaysian Government reimposed a third MCO in both Selangor and Kuala Lumpur in response to the spike in COVID-19 cases. Schools were closed and social and religious activities were banned. After that, on 15 June 2021, a four-phase National Recovery Plan (NRP) was introduced to help the country emerge from the COVID-19 pandemic. Exactly starting from the MCO 3.0 continuing into the NRP and through to the present time, the Mw increased to over the threshold line and reached the peak value and decreased gradually again to the threshold line (Figure 3).

CONCLUSION

Generally, the trends of Mw generation for both Selangor and Kuala Lumpur followed approximately the same shape. Even though Selangor and Kuala Lumpur have similar population densities, Selangor exhibited a much higher Mw generation rate compared to Kuala Lumpur. The mean Mw generation in Selangor and Kuala Lumpur were 7.11385 tonnes/day and 1.90002 tonnes/day respectively. The Mw generation rate in Selangor ranged from 0.05135 tonnes/day to 34.7284 tonnes/day while Kuala Lumpur recorded 0.00395 tonnes/day to 11.376 tonnes/day. The Mw peak during COVID-19 for Selangor is 569% higher compared to the value of Mw before COVID-19 (from 4.3 tonnes/day to 34.7284 tonnes/day). This is a highly significant increase compared to the pre-COVID-19 Mw. For Kuala Lumpur, the intra-COVID-19 value is 94% higher than the pre-COVID-19 threshold (from 4.3 tonnes/day to 8.34522 tonnes/day). This is almost double the pre-COVID-19 value but still five times smaller than the Selangor intra-COVID-19 value. Other than that, exactly starting from the Movement

Control Order 3.0, continuing into the National Recovery Plan, and through to the present time, the Mw has increased to over the threshold line and reached the peak value and decreased gradually again to the threshold line. The Mw may even decrease and be maintained at below pre-COVID-19 Mw generation values for the first time in months if the COVID-19 pandemic ceases.

The rise in the rate of medical waste generation poses additional issues in waste management. The method of treatment and disposal is different according to the characteristics of the waste. All medical instruments and materials used for COVID-19 treatment are considered highly infectious. Aside from transmission in medical settings, the virus can also be transmitted during the various phases of medical waste management (pre-treatment, sorting, storage, delivery, retrieval, transportation, and removal). This demands a more efficient and advanced waste management system to properly dispose of infectious waste.

Healthcare workers must pay careful attention to the control and prevention of medical waste generation. Proper planning, standardisation, and identification of specific medical waste management standards must be explored to decrease the possibility of COVID-19 propagating in hospitals, residential, municipalities, and public spaces. To guarantee proper retrieval procedures, municipal solid waste administrators should arrange designated bins for the handling of contagious or hazardous refuse in crowded areas. All required measures are needed, and realistic guidance should be offered, in order to avoid the transmission of SARS-CoV-2. These recommendations must also consider the impact towards economic and societal factors.

This requires an understanding of the generation rate of medical waste at the national and global levels. More research needs to be done to improve the overall waste management system and ways to decrease COVID-19 medical waste. The long-term future of the Mw will depend on government and public efforts.

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International Journal of Infrastructure Research and Management
Vol. 11 (1), June 2023 pp. 11 - 24

FINITE ELEMENT ANALYSIS OF REINFORCED CONCRETE BEAM-COLUMN CONNECTION WITH KINKED REBAR CONFIGURATION UNDER LATERAL CYCLIC LOADING USING ABAQUS

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ABSTRACT

Plastic hinge deformation is a mode of failure due to earthquake loading commonly found on beam-column joint of a reinforced concrete (RC) structure that adopted strong column-weak beam (SCWB) philosophy. This philosophy is widely used and have been the basic principles of many seismic codes. One research study conducted an experiment with a new steel reinforcement design with kinked configuration with the aim of relocating the plastic hinge deformation away from the beam-column joint to a desirable location on the beam. This design has the potential to improve the usable spaces of a building as stocky column design is no longer necessary. However, all experimental specimens by previous study were found to have only used a single type of concrete grade and the same cyclic loading. Therefore, the deformation of the newly proposed design is mostly unknown under various different conditions. This study aims to analyse the deformation of the new RC structure design under cyclic loading with the implementation of different parametric conditions through finite element modelling using ABAQUS. It was found that the deformation and cracking pattern of the simulated structures are in good agreement with the selected experimental specimen despite being under different conditions. Furthermore, the kinked rebar region was found to have a significant effect on the formation of the initial deformation of the structure under cyclic loading.

Keywords:
ABAQUS, Cracking pattern, Cyclic loading, Kinked rebar configuration, Strong column-weak beam

INTRODUCTION

The Strong Column Weak Beam (SCWB) is a design concept whereby the collapse of a building will not happen instantaneously but rather gradually, which will allow adequate time for the occupants to escape. The adaptation SCWB in most seismic codes have allowed plastic hinge deformation to occur on beam-column connection, preventing the formation of joint shear failure on the structural column (Arowojolu et al., 2019). However, deformation around structural columns during major seismic event is still possible. Therefore, a localised failure at the connecting beam away from the beam-column joint is a more preferred mode of failure than the formation of plastic hinge deformation (Rahman et al., 2016).

An experiment was conducted to analyse the deformation of Reinforced Concrete (RC) beam-column connection with kinked rebar configuration, a new design that is aimed to relocate the deformation away from the beam-column connection under cyclic loading (Qiang et al., 2019). However, even with promising results, the experiment was conducted with only several test samples using the same concrete grade and cyclic loading. Therefore, data on the effects of different conditions on the deformation of the structure are mostly unknown. As a result, further investigations on this new method are recommended due to its practicality and effectiveness in reducing the flexural capacity of the beam (Nie et al., 2020).

Thus, there is a need to analyse the behaviour of structural deformations of the newly proposed steel reinforcement configuration under various different conditions. Simulation modelling using finite element software such as ABAQUS would be more ideal and economical as experimental studies would prove to be costly and also impractical in the time of a pandemic outbreak.

LITERATURE REVIEW

Damages sustained by RC structures after an earthquake event are mostly found in the region of beam-column connection (Feng et al., 2018 and Wong et al., 2008). They are mostly consistent with most simulation and experimental studies. These consistencies prove that structural cracking and deformation patterns are formed as a result of complex ground acceleration of seismic loading which can approximately be predicted even with simple cyclic loading patterns. Therefore, a new approach in structural design is required to avoid structural failures from occurring at the beam-column connection.

Qiang et al. (2019) proposed a novel kinked rebar configuration with the aim of relocating the plastic hinge deformation away from beam-column connection when an RC structure is damaged due to cyclic loading. The design introduces weak points on the structural beam which are strategically placed at the inflection point as the bending moment on the beam is due to vertical loading of zero. Double plastic hinge deformations were found on the beam where the rebars are kinked after the structure was subjected to cyclic loading. The experimental result obtained by Qiang et al. (2019) seemed to be promising as there was barely any deformation found on the beam-column connection.

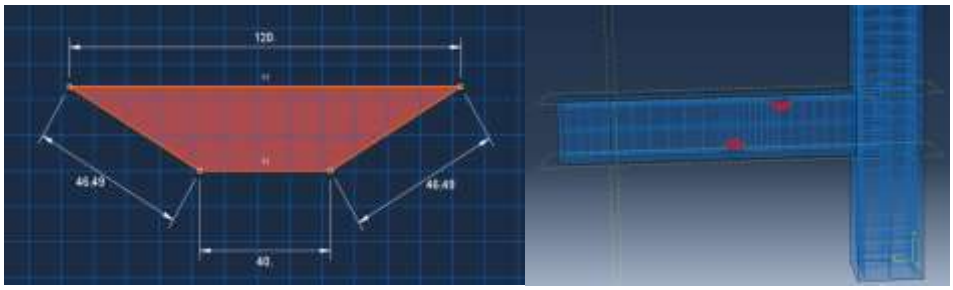
Numerous research studies have been conducted to study the deformation behaviour of RC beam-column joint under cyclic loading. Luk & Kuang (2017) made three different types of finite element models of concrete beam-column structure using ABAQUS with all of them being subjected to cyclic loading. Feng et al. (2018) implemented finite element modelling using ABAQUS to analyse the cyclic behaviour of precast concrete beam-to-column connections using a newly proposed model. Wong & Kuang (2018) prepared seven RC beam-column T- shaped structures based on BS8110 for cyclic loading test with a 1000kN axial load acting on the column. Joyklad & Pimanmas (2011) prepared four RC beam-column joint specimens, all of which satisfy ACI 318. All specimens were subjected to cyclic loading by applying 500kN hydraulic actuator at the top of the column.

Papers covered by all of the researchers mentioned above have found that the mode of failure of RC beam-column connection under cyclic loading are heavily dependent on the structural design. Structures with small column sizes have a higher tendency to develop joint shear failure meanwhile structures with larger column sizes as a result of seismic code design will most likely form plastic hinge deformation at the beam-column connection. This study aims to analyse the deformation of the new RC structure design under cyclic loading with the implementation of different parametric conditions through finite element modelling using ABAQUS.

METHODOLOGY

The steps taken in this research methodology are commonly found in most study involving finite element modelling simulation (Senthuraman et al., 2017). Four models; M-1, M-2, M-3 and M-4 were modelled for the study. Dimensions of the reinforced concrete structure, steel reinforcing rebar spacing and configuration, load configuration and material properties of concrete and steel reinforcement were all modelled based on experimental specimen RCB-KB5 conducted by Qiang et al. (2019). However, it was assumed that the volume occupied by the foam used in the experimental study around the kinked rebar region to be hollowed to reduce the amount of difficulty and computational cost required for the simulation. Model M-1 was modelled closely to experimental specimen RCB-KB5 for verification purpose. Model M-2 was modelled with its kinked rebar region being constrained with concrete rather than having the region hollow. Model M-3 used concrete of higher grade than all other three simulated models. Model M-4 was subjected to a real-life earthquake ground acceleration instead of a simple laboratory cyclic loading that was applied to the other three simulated models. It was also subjected to 1000kN axial load at the top of the column and also a point

load of 7.5kN at the same location on the beam where cyclic loading for the other three models were being applied. The ground acceleration was applied at the base of the column and the direction of the movement was parallel to the beam. Figure 2 shows the dimension of the hollowed regions with a depth of 130mm as well as their corresponding positions in the structure.



(a) (b)

Figure 2: (A) The Dimension of the Hollowed Region with A Depth of 130mm Used to Simulate the Foam Used in The Experimental Study (B) The Positions of Both Hollowed Region in The Structure as Replacement for The Foam Used in The Experimental Study

Concrete damaged plasticity (CDP) model was used to simulate the behaviour of concrete under cyclic loading. The compressive behaviour of the concrete as well as the damage parameters of both tension and compression required in ABAQUS were modelled based on the simplified damage plasticity model approach (Hafezolghorani et al., 2017). The tensile behaviour of the concrete was modelled using the bilinear tensile stress-crack width relationship (Walraven et al., 2013) Table 1 shows the values of plasticity parameters used in ABAQUS. Table 2 shows the data of tensile stress and its crack width relationship used in ABAQUS for all of the simulated models. Table 3 shows the data that are used to simulate the compressive behaviour of all four models.

Table 1: Values Of Plasticity Parameters Used In ABAQUS For CDP Approach

Dilation angle	Eccentricity	f_{b0} / f_{c0}	K	Viscosity Parameter
31	0.1	1.16	0.6667	0

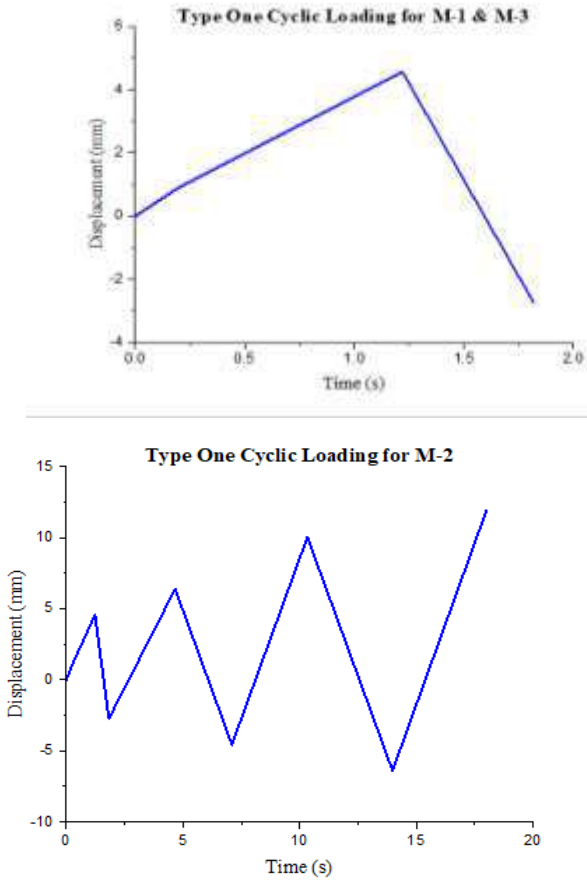
Table 2: Data of tensile behaviour of concrete used in ABAQUS for all models

Concrete Tensile Behaviour Fracture Energy					
Model M-1, M-2 & M-4			Model M-3		
Tensile stress, σ_t (MPa)	Cracking width displacement, u_{ck} (mm)	Damage Parameter, d_t	Tensile stress, σ_t, (MPa)	Cracking width displacement, u_{ck} (mm)	Damage Parameter, d_t
0	0	0	0	0	0
3.765	0	0	4.561	0	0
0.7531	0.187	0.800	0.9123	0.161	0.800
0.038	0.933	0.990	0.046	0.803	0.990

Table 2: Compressive Stress, Inelastic Strain and Damage Parameter Data for All Models Used in ABAQUS

Concrete Compressive Behaviour					
Model M-1, M-2, M-4			Model M-3		
MPa			MPa		
Compressive stress, σ_c	Inelastic Strain, $\varepsilon_c^{in,h}$	Damage Parameter, d_c	Compressive stress, σ_c	Inelastic Strain, $\varepsilon_c^{in,h}$	Damage Parameter, d_c
19	0	0	24	0	0
21.000	0.0000765	0	28.000	0.0001232	0
23.000	0.0001577	0	30.000	0.0001895	0
25.000	0.0002444	0	32.000	0.0002595	0
27.000	0.0003382	0	34.000	0.0003341	0
29.000	0.0004409	0	36.000	0.0004142	0
31.000	0.0005558	0	38.000	0.0005013	0
33.000	0.0006887	0	40.000	0.0005977	0
35.000	0.0008523	0	42.000	0.0007071	0
37.000	0.0010898	0	44.000	0.0008369	0
38.000	0.0014142	0	48.000	0.0014142	0
36.000	0.0018730	0.0526	46.000	0.0018225	0.0417
34.000	0.0020631	0.1053	44.000	0.0019916	0.0833
32.000	0.0022089	0.1579	42.000	0.0021213	0.1250
30.000	0.0023319	0.2105	40.000	0.0022307	0.1667
28.000	0.0024402	0.2632	38.000	0.0023271	0.2083
26.000	0.0025381	0.3158	36.000	0.0024142	0.2500
24.000	0.0026282	0.3684	34.000	0.0024943	0.2917
22.000	0.0027120	0.4211	32.000	0.0025689	0.3333
20.000	0.0027907	0.4737	30.000	0.0026390	0.3750
18.000	0.0028652	0.5263	28.000	0.0027052	0.4167
16.000	0.0029360	0.5789	26.000	0.0027682	0.4583
14.000	0.0030037	0.6316	24.000	0.0028284	0.5000
12.000	0.0030686	0.6842	22.000	0.0028862	0.5417
10.000	0.0031310	0.7368			

All four models are subjected to cyclic loading. Model M-1, M-2 and M-3 are subjected to the same cyclic loading pattern. However, cyclic loading duration of Model M-1 and M-3 will only last up to 1.82 second which is considerably less than Model M-2 cyclic loading which is a full 18 second simulation due to the use of different meshing sizes and also to reduce extensive computational cost. Figure 4 shows the cyclic loading applied to Model M-1, M-2 and M-3. Figure 5 shows a section of Ranau Earthquake loading within the red boundary lines that was used on Model M-4 as a part of observing the structural deformation under real earthquake event.



(a) (b)

Figure 4: (A) Cyclic Loading Applied to Model M-1 And Model M-3 (B) Cyclic Loading Applied to Model M-2

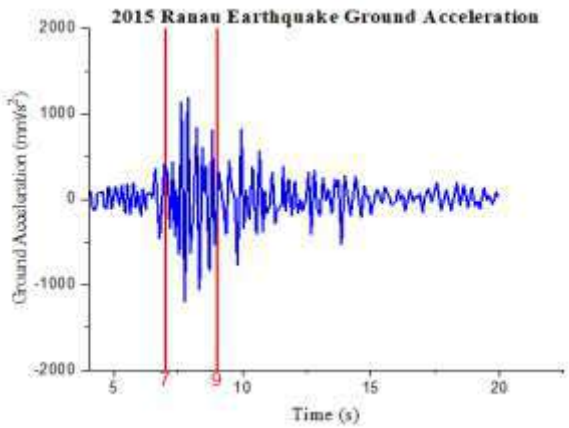


Figure 5: Selected Ranau Earthquake Ground Acceleration That Was Applied to Model M-4

ANALYSIS AND DISCUSSION

Deformation Patterns of All Finite Element Models

Cracking deformation patterns generated by ABAQUS for all four models are shown in Figure 6, 7, 8 and 9. Figure 10 and 11 show the structural deformation of specimen RCB-KB5 that were obtained experimentally for comparison purpose.

It was found that the cracking deformation of Model M-1 is in good agreement with the deformation found in the experimental study despite undergoing cyclic loading for only 1.82 second in the simulation. Model M-2 exhibits minor cracking deformation as compared to Model M-1 at 1.82 second into the simulation due to the additional concrete that constrains the kinked rebar region. However, a combination of severe cracking and crushing deformation can be seen on beam of Model M-2 after undergoing 18 second of cyclic loading. The location of most of the cracking are formed and can be seen in Figure 7(b) are mostly in good agreement with the experimental study despite Model M-2 having its kinked rebar region being fully constrained by concrete.

The cracking deformation pattern of Model M-3 is similar to that of Model M-1. However, cracking deformation is slightly more prominent in Model M-3 due to the use of higher concrete grade which tends to be more brittle (Kwan et al., 2004). Moreover, cracking deformation found on Model M-4 was only due to the 7.5kN point load exerted on the beam. No deformation was found on the column nor on any other parts of the structure due to earthquake ground acceleration. This could be due to the column's remarkable size despite being only 1.8m in height. Therefore, any column related damages due to buckling effect which are often found after an earthquake event could not be seen.

Cracking deformations obtained from all four simulated models heavily suggested that the kinked rebar configuration plays a significant effect on determining the location of the initial deformation of the structure. This is because bent-up steel reinforcement bars can reduce the structure's moment resistance. This finding is in good agreement with the results obtained by Galunic et al. (1977) and Yu & Tan (2014)

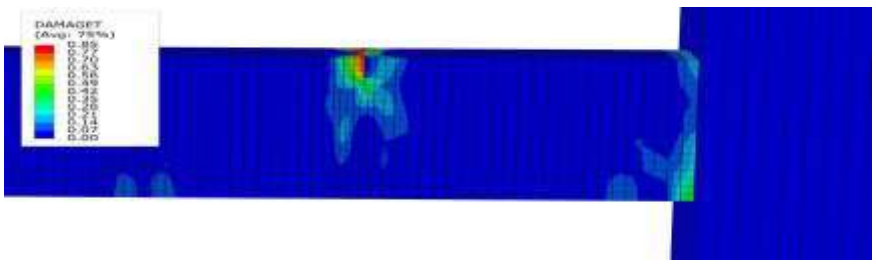
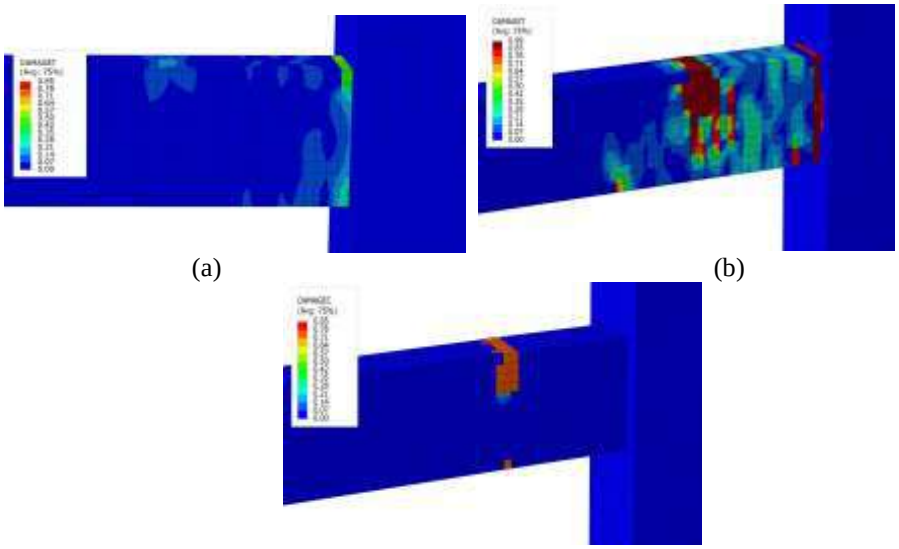


Figure 6: Cracking Deformation Pattern Produced by Model M-1 After Cyclic Loading Simulation (1.82 Second)



(a) (b)

(c)

Figure 7: (A) Cracking Deformation Pattern of Model M-2 At 1.82 Second Simulation (B) Cracking Deformation at 18 Second Simulation (C) Crushing Deformation Due to Compression

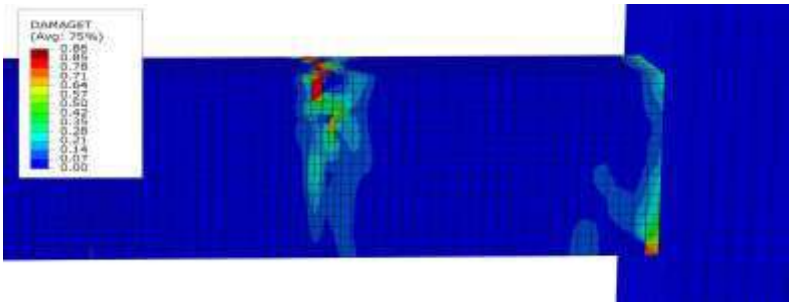


Figure 8: Cracking Deformation Pattern Produced by Model M-3 After Cyclic Loading Simulation (1.82 Second)

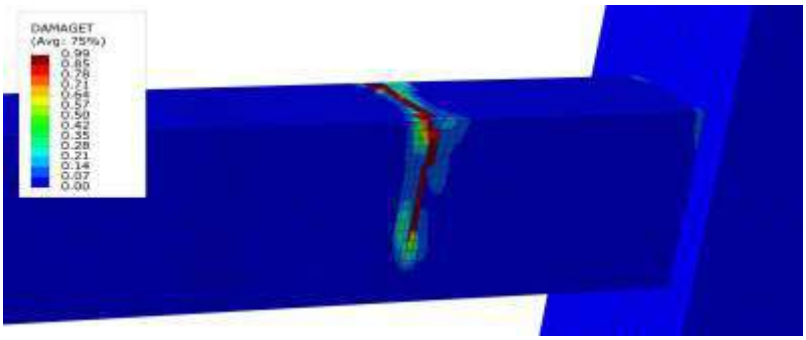


Figure 9: Cracking Deformation Pattern Produced by Model M-3 After Cyclic Loading Simulation (2.00 Second)

(a) (b)

Figure 10: Cracking Formation of Experimental Beam RCB-KB5 by Qiang et al. (2019) (A) Top View of the Beam (B) Bottom View of the Beam

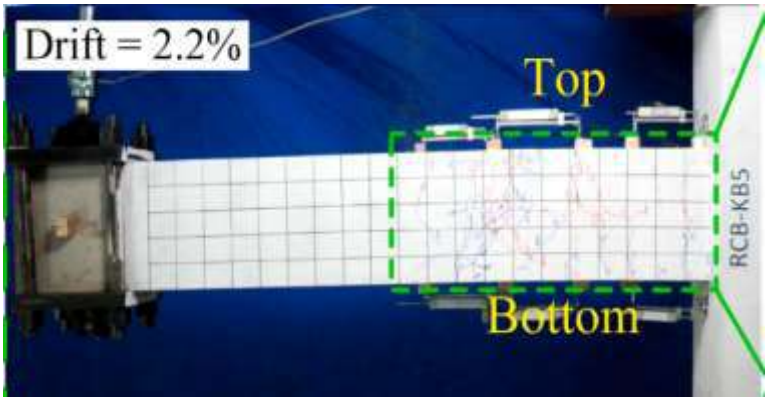


Figure 11: The Cracking Deformation Obtained from Experimental Study by Qiang et al. (2019)

Comparison of Load vs Displacement between Experimental & Analytical

Hysteresis loop of load vs displacement graph of model M-1 and model M-2 in comparison to the experimental result of specimen RCB-KB5 are shown in Figure 12 and Figure 13 respectively. It can be seen that the gradient of load vs displacement in both models are far steeper than the experimental load vs displacement. This is due the absence of pinching effect in the simulation, a phenomenon caused by shear deformation and steel reinforcement slippage along the adjacent of damaged concrete which is commonly found on structural members during reloading phased of a reversed cyclic loading (Deng et al., 2005). This finding is supported by Ab-Kadir et al. (2014) who found that hysteresis curve of load vs displacement obtained in ABAQUS/CAE could not simulate the pinching effect as properly as other finite element software.

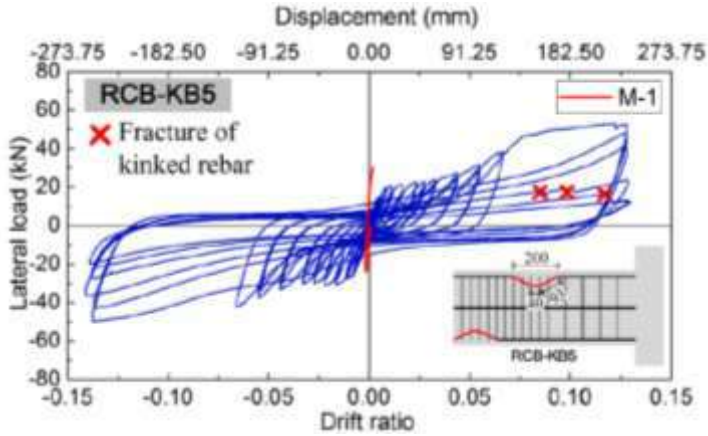


Figure 12: The Comparison of Load Vs Displacement of Model M-1 With Specimen RCB-KB5

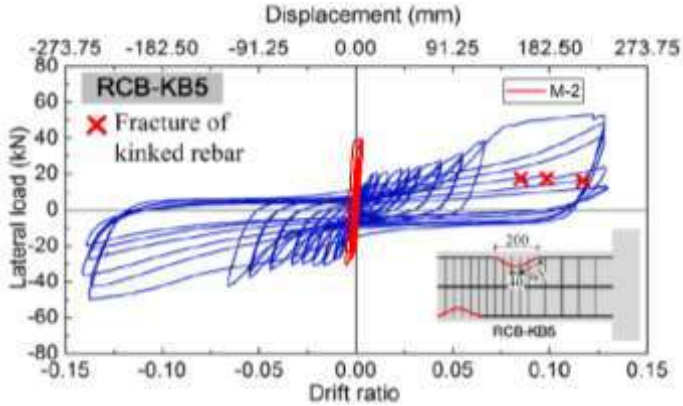


Figure 13: The Comparison of Load Vs Displacement of Model M-2 With Specimen RCB-KB5

Comparison of Load vs Displacement between Models

The comparison of hysteresis loop of load vs displacement between model M-1, M-2 and M-3 can be seen in Figure 14. The main graph shows the load vs displacement of all models with a simulation duration of 1.82 seconds. The smaller graph on the bottom right shows the load vs displacement of model M-1 and M-3 in conjunction with model M-2 18-second simulation. Model M-4 is kept separated as it was subjected under different cyclic loading and also analysed using different approach. All three models were subjected to a downward displacement of 4.559mm before the beam was subjected to the upward movement. The comparison of load vs displacement of model M-1 and model M-3 are mostly in good agreement as more forces are required to displace model M-3. This signifies that model M-3 has a higher stiffness than model M-1 as it uses higher concrete grade. However, specifically for the downward movement, model M-2 required the most amount of load for displacement compared to the other two models. This could be due to the reduction of flexural stiffness in model M-1 and M-3 due to the presence of hollowed regions. However, in the upward cyclic movement, model M-2 was found to be the least stiff out of the three. Although this result is against the author's initial prediction since the absence of hollowed regions should yield a higher

structural stiffness, it was found that the rate of load per unit displacement (stiffness) of all models were heavily dependent on the stress found in the steel reinforcement.

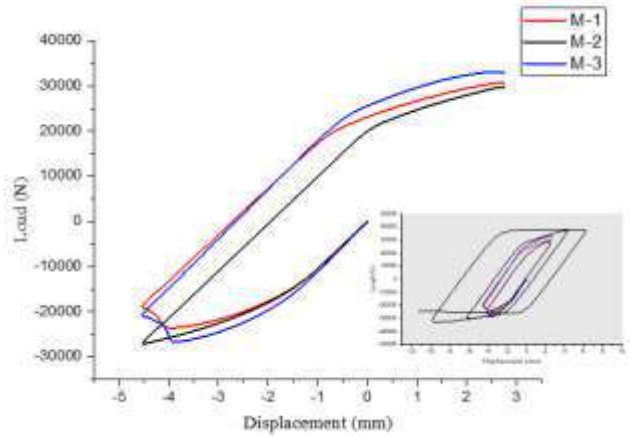


Figure 14: Load Vs Displacement of Model M-1, M-2 And M-3

Figure 15 shows the axial stress vs time of a selected steel reinforcement bar throughout the 1.82 second simulation. The negative stress magnitude indicates that the steel reinforcement is undergoing compression and vice versa. Maximum stress in steel reinforcement was found in model M-2 during the downward cyclic movement. However, it had the least amount of stress when the structure is moving in the upward direction which is completely consistent to the change in stiffness seen in Figure 14. The changes in structural stiffness and stress distribution in the steel reinforcement might be due to the straightening process of steel reinforcement undergone by model M-1 and M-3. This is because, plastic hinge moment capacity of the structure will gradually increase even after large deformation is found since the kinked reinforcement will try to straighten themselves as a result of cyclic movement (Peng et al., 2017). Steel reinforcement in model M-2 could not undergo the same straightening process due to the restraint of kinked reinforcement caused by the additional concrete.

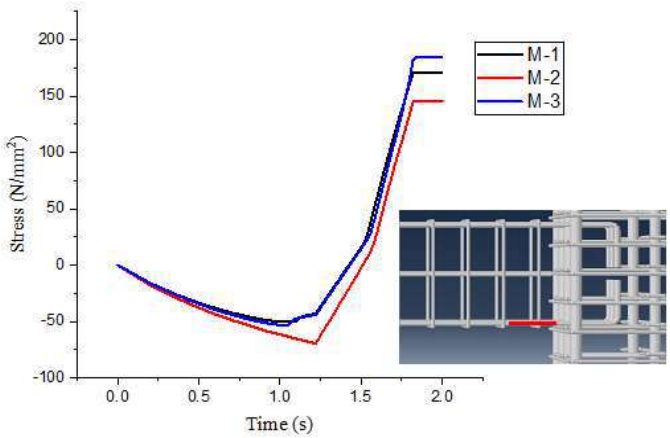


Figure 15: Stress Vs Time of the Selected Element of the Steel Reinforcement Shown in The Image

Figure 16 shows the vertical displacement of a selected node at the kinked reinforcement region throughout 1.82 second. The rate of vertical displacement is measured to compare the rate of straightening process undergone by the reinforcement steel of each model. The result shows a compelling evidence that stress in the steel reinforcement is heavily due to the straightening process. Therefore, the changes in stiffness in the structure is most likely due to the steel reinforcement straightening process. Although this theory is supported with compelling evidence, the sudden change in structural stiffness in a short cyclic period will most likely not happen. Thus, more researches are required to be conducted experimentally and analytically.

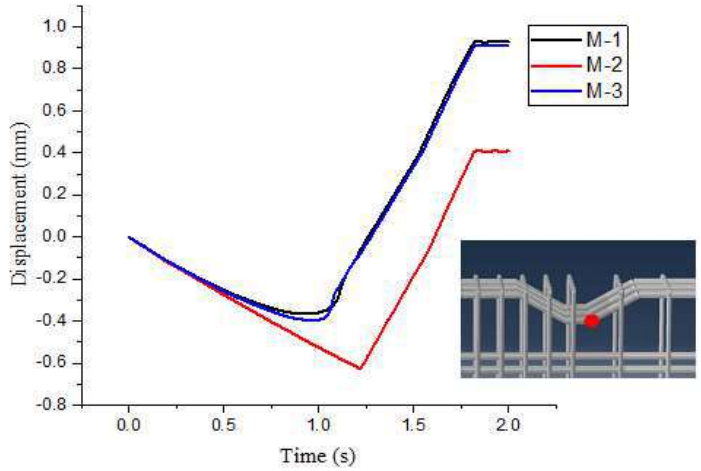


Figure 16: Vertical Displacement vs Time of the Selected Kinked Rebar Node Shown in The Image

Load vs Displacement of model M-4

Load vs displacement of model M-4 was analysed differently as the load could not be obtained through force reaction like the other three models. Therefore, nodal force due to stress element in the y-direction was chosen instead. Figure 17 shows the location of the nodal force. The red node was selected for the analysis as it was the closest to the point where cyclic movement was subjected on the other remaining models (blue node) as analysis could not be done on the exact same location.

Additional filtering is required to be conducted on model M-4 as the result consisted of high frequency noises. Mean values were taken for nodal forces that were recorded at the same time frame. It was found that the displacement of beam was mainly due to the 7.5kN point load and that the earthquake loading barely produce any movement in the y-direction due to vibration.

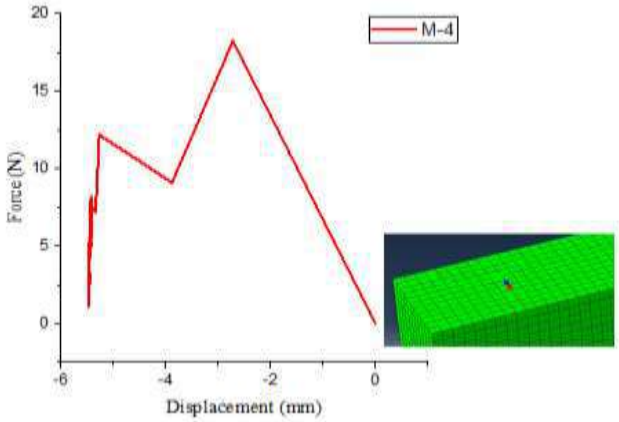


Figure 17: Load Vs Displacement of Model M-4

CONCLUSION AND RECOMMENDATION

The results of all simulation models have found that the kinked rebar configuration is capable of relocating the plastic hinge away from the beam-column joint to a more desirable location on the beam as described by Qiang et al. (2019) Simulation results have found compelling evidence that the kinked rebar configuration played a significant effect in triggering the initial deformation of the structure, despite being under different parametric conditions, due to its reduced moment capacity.

Cracking deformation on the simulated models are also in very good agreement with the experimental result. Most of the deformations are formed within the approximate region of the kinked steel reinforcement.

The comparison of load vs displacement of model M-1 and model M-2 in relative to specimen RCB-KB5 experimental result have shown differences particularly on the steepness of the gradient due to the absence of the pinching effect in ABAQUS CAE software application.

However, analytical comparison of load vs displacement between model M-1 and M-3 are as expected as model M-3 exhibited a stiffer structure due to the use of higher concrete grade. The structural stiffness of model M-2 fluctuated from being the stiffest out of the three (M-1, M-2 & M-2) in the initial downward cyclic movement to the least stiff as upward cyclic movement progresses. Results and data from ABAQUS indicated that it has a high level of correlation with the straightening process that potentially played a major impact in affecting the stress carried out by steel reinforcement in the structure.

No damages on model M-4 were associated to the seismic loading due to its remarkably large column size despite being only 1.8m in height. The damages seen on the beam are solely due to the point load.

It is recommended in the future that Manegotto-Pinto (M-P) model to be applied in ABAQUS to best simulate the slip-bond effect of concrete and steel reinforcement (pinching effect) (Filippou et al., 1983). Moreover, material properties in ABAQUS can be well defined through programming using UMAT sub-routine available in the software to improve the accuracy of the result (Feng et al., 2018).

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International Journal of Infrastructure Research and Management
Vol. 11 (1), June 2023 pp. 25 - 35

ANALYZING THE TRANSLATION OF SHAANXI INTANGIBLE CULTURAL HERITAGE BASED ON OPTIMAL RELEVANCE

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ABSTRACT
Shaanxi intangible cultural heritage (Shaanxi ICH) originated from people's life and practice, reflecting the culture of the local people, and becoming a significant part of Shaanxi's society. Due to variety and quantity, Shaanxi ICH is of great significance in China. Therefore, the translation of Shaanxi ICH could promote the transmission of Shaanxi culture. Translation is a cross-culture communication tool. Due to this, scholars have focused on the translation of Shaanxi ICH as a form of communication and the target readers' acceptance. However, whether the translation achieves optimal relevance has not been proven yet. In order to explore if the translation of Shaanxi ICH can achieve optimal relevance, and identify the reasons for non-optimal relevance in Shaanxi ICH translation as well as the translation strategies of Shaanxi ICH based on optimal relevance, the study did a content analysis and an in-depth interview to compare the English and Chinese versions of eleven Shaanxi ICH. It then analyzed the data from the six interviewed informants selected by using snowball sampling, who were all female, aged from 30 to 60 and served as college English teachers working at Shangluo University for at least ten years. They were all Master's degree holders in the field of translation or linguistics, and were familiar with Shaanxi culture and had at least ten years' translation experience, in particular, Shaanxi culture translation. The study found that the translation inaccuracy of the local place and culture-loaded words, the inadequate translation and the ambiguous translation of cultural-loaded words, and the inadequate information conveyed by the translation of names and places cause non-optimal relevance in Shaanxi ICH translation. In addition, some translation strategies on name, place and cultural-loaded word translation are proposed.

Keywords:
Shaanxi intangible cultural heritage, analysis research, optimal relevance, translation strategies, intercultural communication

INTRODUCTION

Shaanxi, as a province in China, has various kinds of intangible cultural heritage (ICH), including 87 national ICH, which makes Shaanxi intangible cultural heritage (Shaanxi ICH) significant in China. In order to spread Shaanxi ICH to the outside world and promote different cultural communication, translation plays a vital role. However, the research on the translation of Shaanxi ICH is in its infancy. Several scholars including Du and Cheng (2022); He and Wang (2019) Tian and Fu (2018) and Tian (2018) have done research on Shaanxi ICH covering topics from culture translation, research status and problems, to translators' subjectivity. However, translation is not a simple transformation of languages but a form of cultural communication, and the quality of translation has an impact on cultural communication.

A few other studies focus on optimal relevance between Shaanxi ICH and the target readers' understanding and acceptance (Sun, Lian & Tian, 2020; Sun & Lian, 2017). Optimal relevance refers to optimal contextual effect. In processing a text, it is only when the audience acquires adequate contextual effects without making any unnecessary effort, that optimal relevance can be achieved (Sang, 2006). Hence, in translation, when target readers infer from the translation to obtain the meaning of the original text with effective efforts, optimal relevance is achieved. In other words, in the process of translation, translators make the translations of source content optimally relevant to the target readers' cognitive environment. Therefore, optimal relevance as the principle of

communication can be used as a standard to determine if the translation of Shaanxi ICH can be understood by target readers, and achieve optimal relevance and effective cultural communication.

LITERATURE REVIEW

Optimal relevance

Optimal relevance is an important content and principle of relevance theory, which was proposed by Sperber and Wilson in their published book, *Relevance: Communication and Cognition* (Cheng, 2019). The Relevance Theory proposes two principles: the cognitive relevance principle and the communicative relevance principle. Sperber and Wilson define the communicative principle as "Every act of ostensive communication communicates a presumption of its own optimal relevance." and "the optimal relevance is the sufficient contextual effect obtained after the effective effort in utterance comprehension" (Sperber & Wilson, 1996). As Wilson points out, an utterance, being interpreted is consistent with the principle of relevance if and only if the speaker might rationally have expected it to be optimally relevant to the audience (Wilson, 1994).

In 1992, Gutt applied relevance theory to the field of translation studies. He mentioned the definition of translation: a communicative action, and proposed the core criterion of translation is optimal relevance, and the inference process depends on the context. Gutt claims "inherent in ostensive communication is not only that the information she has to offer is relevant to the audience, but that it is optimally relevant" (Gutt, 1992). Therefore, in the process of translation, translators try to get optimal relevance by using different strategies based on the communicative principle of the Relevance Theory (Díaz-Pérez, 2014). In other words, translators try to obtain the relevance of the target reader's cognitive environment and source content to achieve communication with the lowest processing efforts (Szymanska, 2017).

Translation of Shaanxi ICH

The research on the translation of Shaanxi ICH is a new field of study. According to the CNKI database, from 2017 to 2023, there were only 27 papers published in journals related to the translation of Shaanxi intangible cultural heritage, with only a few scholars including Du and Cheng (2022); He and Wang (2019) Tian and Fu (2018) and Tian (2018) having done research since 2011. Firstly, researchers have studied the problems of the foreign propaganda translation of ICH in Shaanxi by seeking data from the internet, websites, previous studies and proposed some strategies. These studies of Shaanxi ICH translation are insufficient (He & Wang, 2019). In addition, the translation of cultural-loaded words was not properly done where Shaanxi ICH was not introduced in detail in the translation. There are also scholars who have studied the culture translation of Shanxi ICH. Sun et al. (2020) recommended the need to choose translation strategies flexibly. In addition, Tian (2018) covered translation strategies, including transliteration and explanation, literal translation, literal translation with description and omission, and making translations understood and accepted by target readers. Tian and Fu (2018) studied translators' subjectivity in the translation of Shaanxi ICH and proposes for translators to be given full play to its subjectivity in the process of understanding and editing the original text.

METHODOLOGY

This study used a qualitative approach, using content analysis and in-depth interviews. English and Chinese versions of the eleven significant Shaanxi ICH, including one humanity intangible cultural heritage and ten national ones were chosen by using purposive sampling. All the samples were from English publications of ICH in China and the English or Chinese publications of Shaanxi ICH. After that, a content analysis was done. The research analyzed the Chinese description of the eleven significant international and national ICH in Shaanxi to obtain the cultural meaning of them. They were then compared to the English and Chinese versions of the eleven Shaanxi ICH to determine whether the translation of Shaanxi ICH achieved optimal relevance. After obtaining their permission, an in-depth interview was conducted with six participants. After the content and data analysis, the research came to an overall conclusion by combining the findings, including the reasons for non-optimal relevance and translation strategies of the optimal relevance in Shaanxi ICH translation.

REASONS FOR NON-OPTIMAL RELEVANCE IN THE TRANSLATION OF SHAANXI ICH

In this study, the Chinese versions and English versions of the eleven Shaanxi ICH were compared based on the optimal relevance. The comparison was done from various perspectives. These include analyzing the deep cultural meaning of Shaanxi ICH, reflecting on the cultural meaning of Shaanxi ICH and the target readers' understanding of the translation. In addition, the English style of describing Chinese ICH as listed in the UNESCO list of Intangible Cultural Heritage and data from the in-depth interviews of the six participants' views on the cultural meanings of the eleven Shaanxi ICH were analyzed. The purpose is to determine whether each item achieved optimal relevance, and if not, the reason why behind it. Finally, the study summed up the reasons why translations of Shaanxi ICH did not achieve optimal relevance.

The translation inaccuracy of the local place

One of the analyses of the English and Chinese versions of the eleven Shaanxi ICH focused on Shanbei as in Shanbei Minge, Shanbei Daoqing, Shanbei Shuoshu. Shanbei actually refers to the northern part of Shaanxi province. Based on optimal relevance, the author intended to transmit the meaning of Shanbei instead of focusing on its pronunciation. However, it was translated as Shanbei in the folk songs of Shanbei, Daoqing of Shanbei, the storytelling in Shaanbei. This only showed the abbreviation of this region instead of focusing on the meaning. So, the target readers would fail to understand the real meaning.

According to Informant 1, Places like Xi'an, Beijing and Shanghai could rely on transliteration but this was not the case for Shanbei, Shannan, Dongbei and the Southwest. This was proven by the book on World Intangible Cultural Heritage in China written by the Compilation Group of Chinese Intangible Cultural Heritage in which only the translation of particular places like Fujian (a province), Xi'an (a city), Nanjing (a city), Longquan (a city) uses transliteration or Pinyin (Shang Guan, & Wu, 2017). Informant 2 said, "Seldom can know Shanbei divided based on the geographic feature of Shaanxi province." Similarly, Informant 4 said, "The target readers are more familiar with Shaanxi than Shanbei which is a basic geographic distribution like a state." Furthermore, Informant 3 said, "The translation Shanbei is hard for the target readers to understand." because Shanbei refers to the northern part of Shaanxi province, which cannot be shown in the translation. In addition, the target readers may be thinking that it is a specific location like a city, a county or a town based on Informant 6. Therefore, the translation of Shanbei is inaccurate.

The translation inaccuracy of culture-loaded words

Based on optimal relevance, the research analyzed the deep meanings of the eleven Shaanxi ICH, compared them with their translation from the meaning of culture-loaded words and the target readers' understanding and combined with the data collected from in-depth interviews of the six participants on the eleven Shaanxi intangible culture heritages to find that the translation of culture-loaded words was inaccurate.

(1) Ansai Yaogu
The Waist Drum in Ansai

One of the Shanxi ICH that the research studied was the Ansai Yaogu which is a folk dance in Ansai County, Yan'an City, Shaanxi Province. It combines dance, martial arts and gymnastics and has become a unique folk art (Jiang, 2008, p. 24). In addition, it evolved from the war drum, martial arts and gymnastics so it is a folk drum dance (Duan & Chang, 2022, p.121). According to the Chinese version, Ansai Yaogu is a folk dance with a drum on one's waist. The translation pertaining to the waist drum only showed that it was a drum on one's waist, which did not reflect the deep meaning of Yaogu and could not be helpful for the target readers to understand this deep meaning. Informant 1 and Informant 6 thought the translation of Yaogu could not achieve optimal relevance because it sounded odd and led to ambiguity so that the target readers cannot understand. Readers would understand it as only a drum instead of a dance. Similarly, according to Informant 2, for the common target hearers, it would be difficult to achieve the optimal relevance. Informant 4 thought the key words of the translation were the waist drum, which seems to mainly show that it is an instrument instead of a dance. Therefore, the translation of the culture-loaded word Yaogu is inaccurate. The informants' thoughts could be found in the following verbatim responses:

Informant 1: "The translation the waist drum in Ansai sounds odd, and it will lead to ambiguity so that the target readers can't know and understand. Therefore, the translation can't achieve the optimal relevance."

Informant 2: "But for the common target readers it is very difficult to achieve the optimal relevance."

Informant 4: "the key words is the waist drum, which seems to mainly show that this intangible cultural heritage is an instrument instead of a dance."

Informant 6: "I do not think this translation can achieve the optimal relevance, and the waist drum can be understood by target readers that it is only a drum instead of a dance."

(2) Yichuan Xionggu
The Chest Drum in Yichuan

Another Shaanxi ICH that was studied was the Yichuan Xionggu which is a folk dance with drums as the fundamental in Yichuan County, Yan'an City, Shaanxi Province. In the dance, women and men performers hold a mallet in their left hand and a cowhide in their right hand with a drum on their chest (Jiang, 2008, p.32). According to the Chinese version, Yichuan Xinggu is a folk dance with a drum on one's chest. However, the translation of the chest drum only mentioned it is a drum performance instead of a dance, which made it hard for the target readers to understand the deep meaning of Xionggu. According to Informant 2, for target hearers, it would be difficult to achieve optimal relevance because the translation could not be understood clearly by the target hearers. This

was supported by Informant 6 who said "The translation of Xionggu only shows it is a drum instead of a dance." Therefore, the translation of the culture-loaded word Xionggu is found to be inaccurate.

(3) Huangling Mianhua
The flour flower in Huangling

The Shaanxi ICH Huangling Mianhua was also studied. It is a unique art made of dough shaped into different animals and flowers. The shaped dough is then steamed, painted and decorated (Jiang, 2008, p.32). According to the Chinese version, it is an artwork made of dough shaped into animals and flowers, just like a bun. The translation only shows the raw material and shape instead of what it really is, which is hard for the target readers to understand. Informant 1 and Informant 6 thought that the translation of Mianhua did not achieve optimal relevance because it could not be understood by the target readers, only that it is made of dough. Similarly, Informant 4 also mentioned Mianhua is shaped into different animals and flowers made of dough. Therefore, the translation of the culture-loaded word Mianhua is inaccurate. Several responses regarding the translation are given below:

Informant 1: "Translating Huangling Mianhua as the flour-flower in Huangling cannot be understood by the target readers."

Informant 4: "Mianhua is translated as flour flower, but actually Mianhua is different animals and flowers made of flour dough."

Informant 6: "I do not think the translation can achieve the optimal relevance. Firstly, the translation of Mianhua only shows the material of flour but actually it is made of dough."

The inadequate translations of culture-loaded words

After an in-depth analysis of the deep meaning of the eleven Shaanxi ICH, and comparing them with their translation based on optimal relevance from the meaning of culture-loaded words and the target readers' understanding and analyzing data of the in-depth interview, the research found that the translation of culture-loaded words was inadequate including for Shanbei Daoqing (Cao, 2011; Jiang, 2008).

Shanbei Daoqing is an old folk singing belonging to Qiyi, originating from the rhyme of Taoists' chant and combined with performance (Jiang, 2008). It is an old song and art form in Northern Shaanxi (Duan & Chang, 2022). The translation of Daoqing only showed the name instead of what it really is so the target readers found it difficult to understand the meaning. According to Informant 1, Informant 2, Informant 3, Informant 5 and Informant 6, the translation of Daoqing did not achieve optimal relevance because it did not clearly show the meaning of Daoqing, and show any related information except for the pronunciation. Furthermore, this translation was not properly done leading to a lack of clarity for the target readers. Similarly, Informant 4 and Informant 6 mentioned the translation failed to deeper meaning of this Shaanxi ICH. Therefore, the translation of the culture-loaded word Mianhua is found to be inadequate. The following are some verbatim responses regarding Shanbei Daoqing:

Informant 1: "Only Daoqing cannot clearly show the meaning."

Informant 2: "The translation cannot achieve the optimal relevance. This zero translation cannot show any related information except the pronunciation. You only know the name Daoqing,

but as for what it means and refers to you do not know. So I do not think the target readers can get any new information from the translation."

Informant 3: "Translation is more improper. When I read the Daoqing, I feel confused and do not know it clearly. Therefore I believe the Pinyin Daoqing cannot be understood by the West people."

Informant 4: "The first word Daoqing and Shanbei are all used transliteration, and the translation cannot show more meaning of the intangible cultural heritage for target readers."

Informant 6: "I do not think this translation can achieve the optimal relevance. The Pinyin only can show what it is called but cannot show the deep meaning of this culture."

The ambiguous translation of local culture-loaded words

The research conducted an in-depth analysis of the eleven Shaanxi intangible cultural heritages based on optimal relevance in comparing the translation from the meaning of culture-loaded words and the target readers' understanding, and analyzed the data from the in-depth interview and found that the translation of local culture-loaded words is ambiguous including for Luochuan Biegu or The Jump Drum in Luochuan (Jiang, 2008; Cao, 2011).

Luochuan Biegu is a folk dance, originating from the army drum for military needs, which is popular in Luochuan County, Yan'an City, Shaanxi Province. The main instruments are drums and the main action is jumping, which is represented by "Bie" in the local dialect (Jiang, 2008). The word jump is used to modify the drum in the translation, which is confusing to the target readers as they find it hard to understand. Informant 2 said "For the common target hearers it is difficult to achieve the optimal relevance." According to Informant 1, the translation could not be understood by the target hearers. There is a misunderstanding about the performance itself as the drum itself cannot jump. This was supported by Informant 6 and Informant 4 who said "Using the word jump to modify the word drum is a mechanical translation, and the translation cannot be understood by the target readers." And "The translation does not show it is a dance, and it will make the target readers confused." Therefore, the translation of the local culture-loaded word Biegu is ambiguous.

The inadequate information conveyed by the translation of names

After the in-depth analysis of the eleven Shaanxi ICH, and comparing the translations based on optimal relevance in the meaning of Shaanxi intangible culture heritages and the target readers' understanding as well as analyzing the interview data, the research found that the information conveyed by the translation of names is inadequate in particular for Huang Diling Jisi or Huangdi Mausoleum Sacrificial Ceremony (Cao, 2011; Jiang, 2008).

Huang Diling is the mausoleum of Emperor Xuanyuan Huangdi, the ancestor of the Chinese nation. People make sacrifices to Emperor Huangdi at his mausoleum (Jiang, 2008, p.164). The translation of Huangdi only showed the name instead of his significance, position and the reason why people sacrifice to him This could not be clearly understood by the target readers. The translation of Huangdi did not achieve optimal relevance because according to Informant 2, the sinologists may know who the term 'Huangdi' refers to but for the general readers they could not know. This is supported by Informant 6 who said "The Pinyin only lets people know his name instead of his states and significance." Therefore, the information conveyed by the translation of names is inadequate.

The Inadequate information conveyed by the translation of places

The data analysis of the in-depth interviews of the six participants on the eleven Shaanxi ICH focusing on optimal relevance, the research found that the information conveyed by the translation of places was inadequate, for example, Ansai, Yichuan, Luochuan and Huangling. According to Informant 2, it is hard to achieve optimal relevance because the target readers were only familiar with developed places like Beijing, Shanghai and Nanjing in China. And Informant 1, Informant 3 and Informant 6 all mentioned the explanation and notes on places like Ansai, Luochuan, Yichuan and Huangling were not clear. Therefore, the translation mentioning these places was found to be inadequate.

Based on the content analysis and data analysis of the in-depth interviews, the reasons why the translations of Shaanxi ICH did not achieve optimal relevance include the translation inaccuracy in relation to the local place, the translation inaccuracy in terms of culture-loaded words, the inadequate translation of culture-loaded words, the ambiguous translation of cultural-loaded words, the inadequate information conveyed by the translation of names and the inadequate information conveyed by the place translation.

STRATEGIES OF OPTIMAL RELEVANCE IN THE TRANSLATION OF SHAANXI ICH

Based on optimal relevance, the analysis of Chinese and English versions of the eleven Shaanxi ICH, the data analysis of the in-depth interview of the six participants' views on the eleven Shaanxi ICH, the translation strategies of Shaanxi intangible culture heritage can be proposed as follow:

The translation of local places

Almost all the eleven Shaanxi ICH are named after the place, such as Xi'an Guyue, Shanbei Minge, Shanbei Daoqing, Ansai Yaogu, Yichuan Xionggu, Ansai Jianzhi, Shanbei Shuoshu, Luochuan Biegu, and Huangling Mianhua, in accordance to the characteristic of Chinese ICH. When translating the local place, at first, translators should lean on the meaning of the place and translate it accurately. Shanbei, for instance, refers to the northern part of Shaanxi province instead of a city, a county or a town. As highlighted by Informant 3 and Informant 6, Shanbei refers to the northern part of Shaanxi province so the translation should be the Northern Shaanxi instead of Shanbei.

In addition, translators should take into account the English reading habits of the target readers and choose proper translation techniques based on the place and optimal relevance to ease the understanding of the target readers. As for places the target readers already know, translators can use transliteration only. For example, Xi'an as a capital city in Shaanxi province can be transliterated as Xi'an, which is the same as that of Ningjing, Longquan, Fujian and Xinjiang chosen from the book World Intangible Cultural Heritage in China written by the Compilation Group of Chinese Intangible Cultural Heritage (Shang & Wu, 2017). According to Informant 6 and Informant 2, Xi'an can achieve optimal relevance because the target readers are already familiar with it. As for the places the target readers are not familiar with, translators should add information about the place in the translation. According to Informant 2, the common target hearers are only familiar with well-known places. In translation, translators should learn more about the place and its location, and then they can use notes or annotations after the transliteration of the place. Informant 3 suggested transliteration with amplification while Informant 6 and Informant 2 said the translation should be based on place and optimal relevance. Taking Ansai, Yichuan, Luochuan and Huangling for example, they can be translated as Ansai, Yichuan, Luochuan counties in Yan'an City, Shanxi Province while, Huangling

as a county in Xi'an City, Shanxi Province or simply as Ansai County, Yichuan County, Luochuan County and Huangling County.

As for the region, translators can use other proper translation techniques. For example, Shanbei refers to the northern part of Shaanxi province, which should not be transliterated as Shanbei but translated as Northern Shaanxi (Duan & Chang, 2022). In translation, translators can explain the meaning of Shanbei by giving further explanations such as it being the northern part of Shaanxi province as noted by Informant 3, or as the plateau in Northern Shaanxi province as mentioned by Informant 2. Alternatively, they also can use literal translation to translate Shanbei into Northern Shaanxi the same as what Informant 1, Informant 4, Informant 5 and Informant 6 suggested. These translations can be easily understood by the target hearers while 'Shanbei' on its own cannot be understood. According to Informant 2 and Informant 6 seldom readers can know what Shanbei is, and the target readers may assume that it is a city.

The translation of culture-loaded words

There are many culture-loaded words in the eleven Shaanxi ICH, including Guyue, Minge, Daoqing, Jianzhi, Yaogu, Xionggu, Biegu, Mianhua, and Jisi. Firstly, when translating them, translators should learn the in-depth meaning and make the translation accurate without ambiguity and information insufficiency. This could be seen when taking Xionggu, Biegu, and Daoqing as examples. Xionggu is a folk dance with drums on the performers' chest. According to Informant 6 and Informant 4, the translation of the waist drum only shows it is a drum instead of a dance so Xionggu should be translated accurately. Biegu is also a folk dance, and Bie a local word means jump. The translation "jump drum" is ambiguous, which can lead to confusion for the target readers according to Informant 1 and Informant 6. So, the translation of Biegu should be accurate and clear. As for Daoqing, it is an old singing from Quyi and originating from Taoist chants. The translation Daoqing only shows what it is called without any necessary information for the target readers to understand as highlighted by Informant 6, Informant 1, Informant 2, Informant 5 and Informant 3. When translating Daoqing, the translators should add more information.

In addition, considering the English habit and the cognitive context of the target readers, translators should choose translation techniques flexibly based on different culture-loaded words and optimal relevance to make the translation easily understood by the target readers. This could be seen when taking Minge, Guyue, Xionggu, Biegu, and Daoqing as examples. Minge is a local song which can be translated as a folk song by using literal translation. This is an equal expression of Minge and can be understood with some effort by the target readers and achieve optimal relevance as highlighted by Informant 3, Informant 4 and Informant 6. Guyue is a large music performance with wind and percussion instruments. Translators can use the free translation technique and translate it as the wind and percussion ensemble, which can help the target readers understand the meaning with necessary effort. This would achieve optimal relevance according to Informant 1, Informant 3, Informant 4, Informant 5 and Informant 6. Xionggu is a folk dance with drums on the performers' chest, and translators can use literal translation and amplification. As noted by Informant 4 and Informant 6 this could be translated to the chest drum dance, which can help the target readers understand the meaning with some effort, achieving optimal relevance. The translation of Yaogu is the same as that of Xionggu. Biegu is also a folk dance, and Bie a local word means jump. So, translators can use transliteration of Biegu with explanation or amplification to explain it is a dance with performers jumping while beating a drum as suggested by Informant 1 and Informant 2. The second way is to use transliteration, literal translation and amplification with notes, explanation or annotation after the transliteration and literal translation of Biegu as suggested by Informant 4 and Informant 6, which can be easily understood by the reader. As for Daoqing, translators can use transliteration with

amplification as Informant 1 mentioned, transliteration with explanation or annotation based on Informant 2, Informant 3, Informant 5, Informant 4 and Informant 6.

The translation of people's name

Some of the eleven Shaanxi ICH are named after people's names like Mulan Chuanshuo and Huang Diling Jisi. When translating people's names, firstly, translators should learn more about the person in question to avoid inadequate translation. Huangdi is a classic example. According to the participants, Huangdi is an ancestor, a king or an emperor in Chinese history. Informant 2, Informant 4 and Informant 6 mentioned the translation of Huangdi only shows his name instead of other information, which is inadequate. So, translators should add more information to avoid it.

In addition, translators should take full account of the target readers' cognitive context and choose proper translation techniques. In this case, Mulan and Huangdi serve as good examples. Hua Mulan is the hero of legend which has been filmed twice by Hollywood. In this case, the target readers would be familiar with the name. According to the English title of the film Mulan, Hua Mulan can only be transliterated as Hua Mulan, which can be easily understood by the target readers according to the participants. As for Huangdi, the target readers would not know much about him. If translators use transliteration, the target readers will only know his name but not the person he was. Huangdi was a great emperor in Chinese history so translators can add the word emperor before Huangdi to let the target readers know his important position as suggested by Informant 4, Informant 3 and Informant 6 or provide a further explanation after Huangdi as highlighted by Informant 2.

From the content analysis and data analysis of the in-depth interviews, in translating local places, at first, translators should learn the meaning of the place and translate it accurately. In addition, they should base the translation on the English language habits of the target readers to choose proper translation techniques to achieve optimal relevance to let the target readers understand. These techniques include transliteration, transliteration with notes, annotation or amplification, free translation, or literal translation. In translating cultural-loaded words, translators should learn the in-depth meaning and make the translation accurate without ambiguity and information insufficiency. In addition, considering the English language norms and the cognitive context of the target readers, translators should choose translation techniques flexibly based on different culture-loaded words and optimal relevance, including literal translation, free translation, literal translation with amplification and transliteration with explanation, annotation or amplification, equal expression, transliteration, literal translation and amplification with explanation, notes or annotation to make the translation easily understood by the target readers. In translating names, firstly, translators should learn more about the people to avoid inadequate translation. In addition, translators should take full account of the target readers' cognitive context and choose proper translation techniques, including transliteration and transliteration with amplification.

CONCLUSION

Shaanxi ICH, as a significant culture with variety and quantity, takes an important position in China. The translation of Shaanxi ICH can promote the spread of Chinese culture. Translation is a communication activity that crosses between different cultures. Communication is the purpose of translation, and translation is the means of communication between different cultures. Therefore, the quality of translation has a great influence on communication. The study has applied optimal relevance to analyze the translation of Shaanxi ICH because it can guide successful communication in translation, and can be used as a standard of translation. The principle of effective cultural

communication could be enhanced by doing a content analysis and in-depth interviews to find the reasons behind the translation of Shaanxi ICH which has not achieved optimal relevance and propose strategies for optimal relevance in Shaanxi ICH translation. By doing this, translators can achieve optimal relevance and effective communication of Shaanxi ICH via translation, and this could make up for the deficiency of previous research.

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International Journal of Infrastructure Research and Management
Vol. 11 (1), June 2023, pp. 36 - 52

DEVELOPING INTERACTIVE E-LEARNING CONTENT: A SUBJECT MATTER EXPERT PERSPECTIVE

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ABSTRACT
The COVID-19 pandemic has compelled universities worldwide to adopt online teaching and learning as a necessary measure. However, the rapid transition to online learning has presented challenges for educators in selecting appropriate practices and technological content to deliver effective education in the online environment. Concurrently, students have reported feeling overwhelmed with numerous tasks and an excessive amount of information. This study addresses the research problem by focusing on the design and creation of suitable Management Information System (MIS) e-learning materials tailored for graduate students. The Waterfall Model serves as a reference framework for this investigation. The study participants were 25 highly knowledgeable subject matter experts (SMEs) with experience in e-learning. The data processing was carried out using the Scale Ranking Type. Additionally, the study explores the use of HTML5 Package (H5P) in blended learning through the Moodle learning management system (LMS) platform and evaluates the perceptions of SMEs through a survey. The results indicate that SMEs prioritize integrated approaches, flip methods, task-centered strategies, presentation techniques, and hybrid styles when delivering interactive visual information for master's level Information System courses. The evaluation of students' performance in MIS subjects demonstrated a significant 75% improvement in various learning outcomes.

Keywords:
IR4, Education 4.0, e-learning, information system, interactive visual content.

INTRODUCTION

Education 4.0 is a revolutionary experience-based education system that leverages digital technology instead of rote and personalised learning (Frederick, 2019). This approach combines technology, individualism, and discovery-based knowledge to teach future generations about Industry 4.0 (Xu e al., 2018). The application of technology has had a positive impact on education. Higher education also emphasises the use of digital technologies. Although most educators in higher education continue to employ conventional methods, they also make excellent use of technological tools in the classroom and online. Creative manipulation of multimedia elements such as text, graphics, animation, audio, and video are applied to the learning materials to supply a more engaging environment for learning. Self-learning is promoted through website application platforms such as Learning Management Systems (LMS). Technology in education can foster a creative, innovative, and competitive generation prepared to confront the challenges of the 4.0 Industrial Revolution, where humans and computers work together to solve problems, generate innovative ideas, and raise the quality of life (Sharma, 2019).

For this reason, educators must become proficient in Information Communication Technology (ICT) to transfer their knowledge through online teaching and learning (Dela Fuente & Binas, 2020). Content development for online learning includes the creation of instructional materials and learning activities, the design of interactive courses, the creation of quizzes and evaluations, and the incorporation of multimedia elements. Frequently, content development is used to create e-

learning materials and digital content. It can take any form, including text, photographs, video, audio, and animation (Khojasteh e al., 2022).

Problem statement

The COVID-19 pandemic has necessitated universities globally to turn to online teaching and learning, which has created a new challenge: choosing the appropriate practices (approach, method, strategy, technique, and style) and technological content to effectively deliver education in the online environment (Zhang et al., 2022; Smith et al., 2022). Figure 1 shows the results of a study conducted by Al-Kumaim et al., 2021 on the challenges among students during the pandemic related to online learning. Two-thirds of the university students (69.5%) who participated in the study felt overburdened when following up with their online courses, while 30.5% of the students reported no sensations of overload.

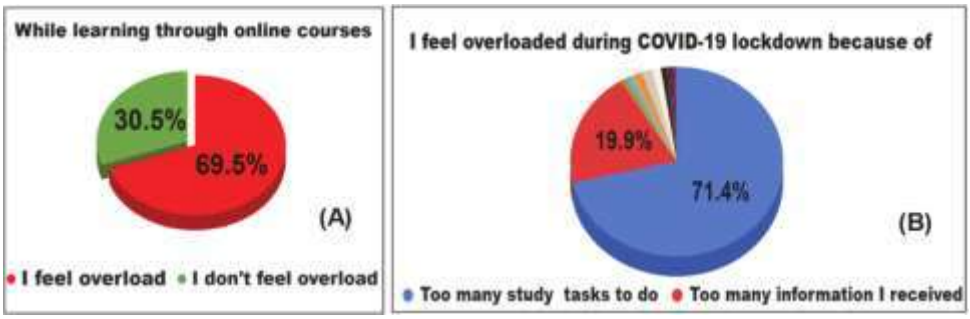

Figure 1: Students overload feeling and causes during online courses. A: Students' overload feeling; B: Causes of information overload during online courses (Al-Kumaim et al., 2021)

The preliminary study shows there are three main challenges among students and educators during the pandemic in relation to online learning: a lack of interactive content, a lack of appropriate resources, and a lack of professional development opportunities. During the pandemic, most of the educational content delivered online was in the form of static visual material, such as images, slideshows, and presentations (Arunaz et al., 2021). This is because the transition to online learning was hasty. According to Doe's research in 2023, educational content must be delivered considering the needs of learners, the goals of the course, and the available resources.

Additionally, there is a lack of high-quality, affordable online learning resources available to students. This can make it difficult for students to find the resources they need to succeed in online learning. Furthermore, many educators lack the training and skills necessary to teach effectively in an online environment. This can make it difficult for educators to create engaging and effective online learning experiences for their students. Educators are supposed to provide clear instructions, use interactive activities, and offer opportunities for students to collaborate with each other (Roe, 2023).

Objectives

The goal of this study was to address key aspects within the field of online teaching and learning of a Management Information System (MIS) subject. The first objective involves a thorough analysis of various approaches, methods, strategies, styles and material delivery philosophies that are particularly appropriate to the online teaching and learning environment. This evaluation seeks to identify the ideal practises for MIS education delivery in an online environment.

The second objective centers on the development of learning content tailored to the preferences and expertise of subject matter experts (SMEs), utilizing the Moodle LMS and HTML5 Package (H5P) platforms. This objective implies utilising these platforms to create and alter instructional materials in accordance with the preferred instructional design and learning styles of the SMEs. By accomplishing this objective, the study aimed to provide valuable insights into the utilization of these platforms for the enhancement of the online learning environment in the MIS subject.

LITERATURE REVIEW

E-learning vs Blended Learning

E-learning, also referred to as online training or distance learning, is a digital form of education that leverages information and communication technologies such as computers, smartphones, and tablets. E-learning programs comprise learning modules designed for individual or group learners and employ a variety of forms such as text, video, audio, and quizzes. Educators utilize a learning management system to manage and conduct the e-learning program. The convenience of e-learning is that students can complete their learning from their desks, and mobile learning is accessible both online and offline, enabling anytime, anywhere learning. Despite its benefits, e-learning was not delivering the desired outcomes, leading to the development of blended learning. Blended learning, also known as hybrid learning, merges traditional classroom instruction with online content and technologies (Singh et al., 2021). The term "blended learning" was first used in the 1990s to describe the integration of computer-based instruction with conventional teaching strategies (Kwak et al., 2015; Akcil & Bastas, 2021).

Blended learning is a unique approach to education that brings together the benefits of in-person and online learning. It encompasses various elements such as e-learning modules, virtual classes, in-person instruction, and group activities through web chats or forums (Awal Kurnia et al., 2021). This form of learning provides greater flexibility and adaptability in training courses. By combining both synchronous and asynchronous learning, blended learning delivers personalized learning experiences for students. It is a more effective teaching method as it combines the theoretical aspects taught through e-learning modules and the hands-on aspect taught in person. The COVID-19 pandemic has led to a significant increase in the popularity of blended learning as online and distance education become more prevalent. Even those who are not fully prepared for online environments are adopting blended learning (Widyawan et al., 2020). The advancement of technology, such as mobile devices, interactive whiteboards, and online resources, has further enhanced the widespread acceptance of blended learning as a teaching technique.

Some researchers claim that blended learning models can improve student learning competence since students conduct more learning activities such as observing, undertaking, presenting, creating, and transferring (Lim et al., 2019). Students have access to the content and resources available online in a blended learning environment, which allows them to augment the education they receive in traditional classroom settings. The content that is available online can either be used for independent study or as part of an online class. Significant benefits of a blended learning strategy include engaging students and aiding in their knowledge retention. According to research, blended learning enhances learning, reduces failure rates, and increases student engagement (Vallee et al., 2020)

The literature suggests that e-learning with interactive features and multimedia-rich information can increase its efficiency. One approach to achieving this is by utilizing H5P interactive visuals as instructional resources, which align with the fundamental principles of blended learning. The H5P content can be integrated into the Moodle LMS platform to provide an interactive and enjoyable learning experience among learners.

Approach, method, strategy, technique, and style in teaching and learning

A teaching approach can be described as the methods or techniques a teacher uses to deliver instruction and engage students with the subject matter (Akimenko, 2016). It represents a set of guiding principles, beliefs, and theories about learning that inform a teacher's classroom practices (Nasiba et al., 2021). Essentially, a teaching approach is what distinguishes one teacher's method of teaching from another, and how they aim to achieve the desired educational outcomes (Jesús et al., 2022). Thus, it provides a philosophical framework for the overall teaching process.

In the context of teaching and learning, a teaching approach refers to the systematic method employed by a teacher in organizing and delivering educational content and activities to meet specific learning goals. The effectiveness of a teaching approach can be evaluated through comprehensive educational assessment to ensure that students receive the proper knowledge (Leovigildo et al., 2021). To maximize the impact of teaching, a combination of approaches should be employed to meet the diverse needs of students and to provide a dynamic learning experience (Ismail, 2013). Effective teachers are those who are proactive in exploring new methods and techniques, and who are willing to adapt their approach when necessary to meet the changing needs of their students (Veda, 2021). Thus, a teaching approach should be flexible and continuously evolving to ensure optimal educational outcomes.

The procedures used to help students learn course material and achieve their goals are referred to as teaching strategies (Ravindra, 2018). These strategies take into consideration different learning methods, allowing teachers to design the most effective plan for their target group of students (Abulhul, 2021). The COVID-19 pandemic has heightened the need for creative and innovative teaching strategies, especially for online learning. Utilizing technology such as computers, laptops, and the internet has proven to be incredibly beneficial in facilitating online teaching (Norita, 2021). The widespread adoption of technology-based teaching strategies by universities worldwide during the pandemic has highlighted the importance of embracing technological advancements in education.

Teaching techniques are methods utilized by teachers to achieve optimal results during instructional sessions. These techniques involve the practical application of skills and strategies to support student learning. According to the Collins Dictionary, a technique is defined as a specific method or activity (Collins, 2022), while the Cambridge Dictionary defines it as the skilful execution of an activity (Cambridge, 2022). To put it simply, teaching techniques are a collection of resources, technologies, and attitudes that teachers use to clarify and solidify learning objectives. They are key to enhancing the educational process and can be used to improve curriculum, instructional methods, and teacher competencies.

In essence, a teaching approach is a plan that outlines the desired outcomes and what is feasible. A teaching technique refers to the specific tools and actions used by the teacher to achieve specific goals. A teaching method, on the other hand, is a set of guidelines that dictate what should or should not be done in certain situations. A teaching strategy is an educated guess about what will be most effective in helping students learn. Understanding these terms is crucial in creating and implementing educational content that caters to the needs of both students and educators. By considering the learning style of students, the learning process can be made more effective and efficient.

Learning Theories

Many people around the world use e-learning as a modern way to teach. Many online materials do not meet good teaching and learning standards, highlighting the need for rules to structure online materials for effective learning (Muhajirah, 2020). Learning theories were developed so that researchers could better understand and predict the learning process. Since their job is facilitating learning, e-learning experts should understand how that process works. This section looks at behaviorism, cognitivism, and constructivism learning theories and conveys the principles that can be applied in e-learning settings. The implications of these principles are discussed to show how e-learning can be used to help students learn and to help engage them.

Behaviorism is one of the most prevalent learning theories (Scheer et al., 2012). This idea was first proposed by John B. Watson and later expanded by B.F. Skinner (Moore, 2010). This theory is founded on the premise that all human behavior can be explained by a person's environment and past experiences. Skinner argued that all human actions, including language and thought processes, may be learned through conditioning (Burhanuddin et al., 2021). As the term implies, a behavioristic approach focuses on helping students reach learning goals that have already been set. When learners get these expected outcomes, which are meant to meet the learning goals of the e-learning course, this is seen as learning. So, the purpose of an Instructional Design strategy for e-learning based on behaviorism must be to give learners the right stimuli, that is, opportunities to demonstrate that they can express desired behaviors that prove that learning has taken place (Samaduzzaman, 2021).

Cognitive psychologists study mental processes such as attention, memory, problem-solving, perception, and language processing (Dolegui, 2013). The cognitive perspective emphasises the significance of mental functions in comprehending how individuals think, remember, and solve issues (Bandono & Suharyo, 2021). Cognitive learning promotes continuous learning and long-term learning. It connects students' prior knowledge with new material to successfully use it. Cognitive learning enables students to comprehend in detail, hence fostering comprehension. Thus, learner comprehension is enhanced (Ghazali et al., 2021). Students will also apply the techniques with confidence. Cognitive learning allows students to better comprehend the subject matter by exploring it. Students can develop practical problem-solving abilities through cognitive learning.

According to the constructivist perspective, all knowledge is produced and subject to change (Alzahrani & Woollard, 2013; Shah, 2019). Constructivists believe that learners construct meaning through interactions with their environment and that these meanings can be shared with others to build a shared understanding (Grady et al., 2018). This idea significantly supports the adult learning strategy. An online teacher is a facilitator or tutor overseeing and providing students with essential skills and knowledge. To properly administer online courses, online educators must first understand the characteristics of online adult education. Adult students, according to Knowles (1975) and Brookfield (1985), are responsible for their education and their lives. Adults must comprehend why they must invest in each circumstance. The success of online courses can be increased if online educators better understand their students (Bada, 2018).

In conclusion, all the theories discussed have a significant role in building e-learning content. Each idea gives a different view of how students learn and what they need to do to learn. The behaviorist learning theory is still employed in online courses, typically in drag-and-drop exercises, to organise content into relevant categories. In this framework, feedback plays a crucial role in determining whether a person's actions are appropriate. Additionally, the theory of cognition is also highly significant. Social cognitive learning is utilised in e-learning as social learning. Cognitive behavioral learning is employed by reminding earners of concepts they already know at the beginning of a course to activate brain nodes relating to the subject.

On the other hand, the constructivist learning theory is the most extensively employed by eLearning practitioners today. The principle is applied in e-learning by presenting learners with real-life perspectives through storytelling or simulation, providing learners with something to relate to or

emotionally connect. E-learning professionals must use various e-learning strategies while keeping in mind the learning theories they follow to help modern learners learn and remember things better. Every theory has changed how educators teach and do something; innovative ideas will do the same in the future. Therefore, e-learning designers must begin training design by determining the purpose of the training. They must then choose the proper theoretical framework or a mix of frameworks to help learners reach their learning goals.

Content development model

The Waterfall Model is a development model for educational materials used in this study as shown in Figure 2. This model consists of five key stages: requirement analysis, design and development, implementation, testing and evaluation, and maintenance. The systematic approach of the Waterfall Model ensures all necessary processes are completed to develop successful applications and produce effective learning content. The study started with requirement analysis, where the problems of SMEs in the MIS course were identified through a literature review and questionnaire. The design and development stage involved the creation of the User Interface (UI), flowcharting and providing the application content, video, tutorial, ePUBs, and H5P interactive content.

The implementation stage involved the implementation of the application design into a program using the Moodle learning management system. The testing and evaluation stage was carried out using Black Box Testing to evaluate the performance of the e-learning system platform and interactive content. The subject of this study was used to test the functionality and usability aspects of the application, with the functional suitability test being carried out by expert respondents and SMEs with experiential learning and understanding of e-learning materials.

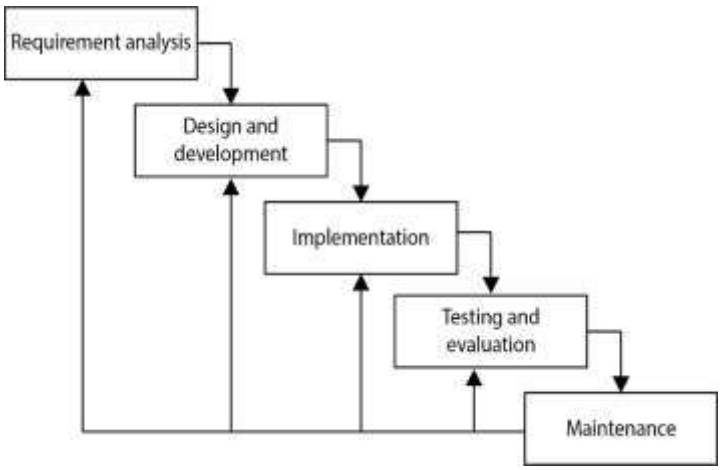

Figure 2. Stages of the Waterfall Model (Adeagbo et al., 2021)

In conclusion, the Waterfall Model is an effective model for developing educational materials, as it ensures all necessary processes are completed in a systematic manner. The study demonstrates the implementation of the Waterfall Model to produce an e-learning system platform, with a focus on evaluating the functionality and usability aspects of the application.

Moodle and H5P

Moodle is a system for managing different classes used in various educational settings. It is designed for collaborative learning; therefore, it makes sense to utilise H5P. H5P is interactive content based on PHP to develop, manage, and publish material (Singleton & Charlton, 2019). It interacts well with Moodle, making it excellent for managing course content. With H5P, the H5P library content can be integrated directly into Moodle courses, making it simple to incorporate high-quality scientific content. H5P is also compatible with several major learning management systems (LMS), including Blackboard, Canvas, and Brightspace. H5P is extremely user-friendly and may be modified to match the demands of the students.

H5P enables the creation and distribution of interactive multimedia content, including presentations, quizzes, games, and more. In addition, the learning materials are frequently updated so students can always access the most current knowledge. It is a content production tool for creating and editing HTML5 documents. It was discovered that H5P could efficiently empower students in e-learning courses (Mir et al., 2021). The Open University of the Netherlands (OUNL) discovered that students who utilised H5P to develop and share their learning content had a more positive perspective on their education than those who did not.

H5P has several benefits, including the ability to create rich media content, simplicity of use, adaptability, and the capacity to share content with others (Addhiny, 2022). However, there are disadvantages to adopting H5P, such as its limited ability to track learner interactions, the requirement for a robust internet connection, and its incompatibility with all browsers and devices. Despite these shortcomings, H5P continues to be a popular alternative for those who develop content for online learning and provides students with an excellent opportunity for online education. Users can begin quickly and effortlessly to start their learning experience (Unsworth & Posner, 2022). The UI is intuitive and well-organised, making locating the desired resources and courses simple.

H5P is also a plug-in for Moodle that allows instructors to create interactive digital books called ePUBs for online learning. With H5P, instructors can add audio and video to their ePUBs and create interactive exercises. ePUBs may be read on a computer, tablet, or smartphone. The books are saved in an electronic format after being downloaded to the user's device. The content is presented in a way that is intended to be more engaging and participatory than a conventional book (Hanif et al., 2019). Not only is it beneficial to the health of the eyes, but it is also beneficial to the environment, as it does not result in the production of any waste, and it reduces the amount of paper used. It can also be utilised to conserve space because fewer books are required as physical copies. The key features that make it effective are: (i) it provides the learner with a customised experience, (ii) it is compatible with mobile devices, (iii) it offers simple navigation via hyperlinks, and (iv) it includes multimedia content. As a result, educators or instructors should adopt this new format, which has proven successful in several ways (Nasrulloh et al., 2018).

METHODOLOGY

Digital questionnaires were distributed to 25 SMEs in the field of Information Systems (IS). They are facilitators in this domain with over five years of teaching experience in public and private universities. During the pilot test phase, a questionnaire was distributed to four professionals specializing in IS to gather their feedback. The limited number of experts involved in the pilot test facilitated the collection and analysis of input, enabling a more thorough and focused evaluation of the outcomes. Additionally, this smaller group allowed for efficient decision-making based on the feedback received. The selection of these four respondents adheres to the typical guideline of 10-20% of the full-scale survey sample size.

Scale Ranking Type (SRT) questions establish how the facilitator prioritised. The SRT required respondents to compare a range of variables and utilised the principle of multiple-choice questions. When a facilitator decides to be influenced by multiple elements, each aspect has a different priority in the decision-making process. Education researchers employ SRT questions to identify which feature of a teaching approach, method, strategy, technique, or style they valued the most. It is often utilised for educational research throughout the pre-production and post-production phases.

Based on the result, contents for one of the MIS courses were developed with modification to the basic ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model as shown in Figure 3. In this approach, users' wants and experiences could be captured, and content could be tailored to the intended audience. The integrated strategy for designing this system provided a robust and dependable procedure due to the combination of the ADDIE and SDLC (Software Development Life Cycle) models. Student assessment results before and after the implementation of this newly developed contents were compared to see the effectiveness of this approach.

The ADDIE model was used for instructional design and training development projects, whereas the SDLC model was utilised for software development projects. Both models, however, have similarities in their repetitive character and emphasis on evaluation. An institution can include instructional design ideas in the software development process by combining the two models. This integration can ensure that training and user demands are considered throughout the development lifecycle and that the final software product matches the instructional objectives.

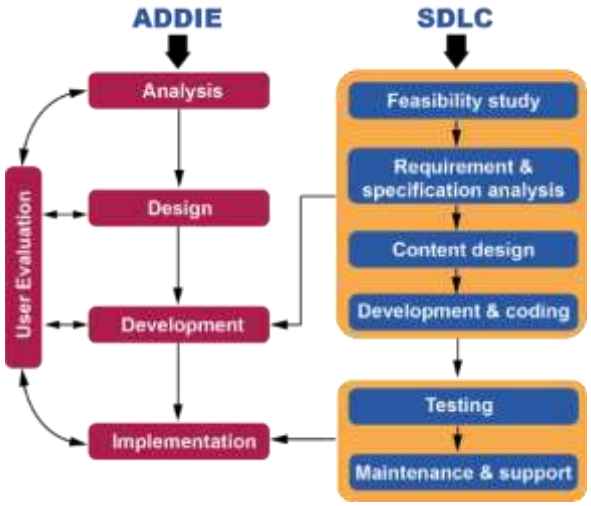

Figure 3: ADDIE and SDLC synergy

In this study, the Analysis phase of the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model was utilized to identify user needs and learning objectives, which was then incorporated into the Software Development Life Cycle's (SDLC) requirements gathering phase. By integrating the ADDIE Design phase into the software design process, the UI and interactions were aligned with instructional methodologies. During the Development and Implementation phases, careful consideration was given to designing and deploying software that prioritized instructional content and usability. Moreover, the Evaluation phase of ADDIE was seamlessly integrated into the SDLC's testing and quality assurance processes, allowing for an analysis of the software's effectiveness in meeting instructional goals. The combination of ADDIE and SDLC offered a comprehensive approach that considered both instructional design and software development components, ultimately leading to a more successful and user-centered final product.

RESULT AND DISCUSSION

Education is a continuous process that requires continuous improvement to keep pace with the changing demands of society. In recent years, there has been a significant shift in the way education is delivered, with the increasing use of technology and the rise of online learning. With the rise of technology-based teaching methods, it is crucial to understand which strategies are most favored by SMEs and how they are impacting student performance. To gain insight into this, a survey was conducted to gather data from SMEs in the field of MIS, focusing on their favored teaching and learning approaches. The results were analyzed and presented in six figures (Figure 4 to Figure 8), each of which provides a comprehensive overview of the most favored methods and their impact on student performance.

Finding and Discussion on Teaching Approaches

The results of the Rank Analysis, presented in Figure 4, indicate a clear preference among SMEs for integrative approaches, with 29% of respondents favoring this method. The inductive and deductive approaches followed closely behind, at 24% each, with elective approaches trailing slightly behind at 23%. This result suggests that the integrative method leads to improved student performance in learning modules. This finding aligns with the existing literature on teaching approaches, which suggests that a combination of approaches should be employed to meet the diverse needs of students and provide a dynamic learning experience (Ismail, 2013). This approach integrates students' abilities, prior knowledge, and cognitive processes, fostering a more comprehensive understanding of the subject matter. Furthermore, it challenges students to apply their knowledge in innovative ways, promoting their critical thinking skills and creativity.

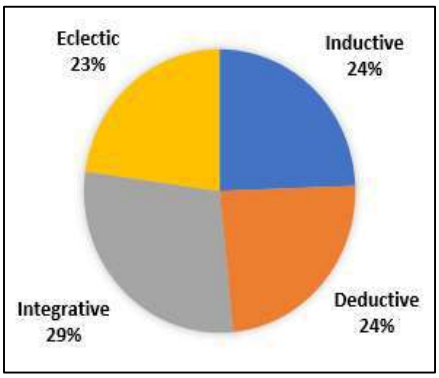

Figure 4: Teaching approach

The results of the Rank Analysis, presented in Figure 5, highlight a strong preference among SMEs for flipped methods, with 23% of respondents indicating their preference for this approach. The Direct method followed closely behind at 22%, with personalized methods at 20%, inquiry methods at 19%, and expeditionary methods at 16%. The results indicate that the flipped method is a highly effective teaching approach, particularly in terms of enhancing student engagement and comprehension. By flipping the traditional classroom structure, educators were able to personalize instructions based on student performance data gathered through assessments and quizzes. This finding supports the notion that teaching methods are a collection of resources, technologies, and attitudes that educators use to clarify and solidify learning objectives (Collins, 2022).

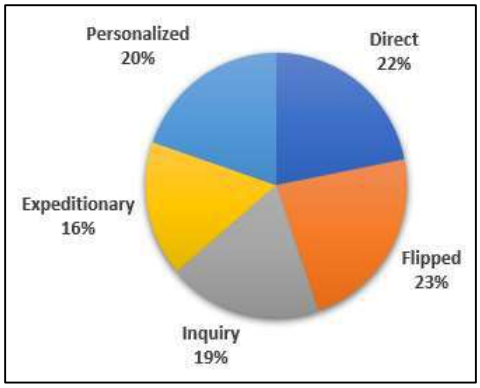

Figure 5: Teaching method

According to the Rank Analysis presented in Figure 6, it can be observed that Task-Centered Strategies were highly favored by SMEs, with the highest percentage of 29%. This is followed by Activity-Centered Strategies (28%), Learner-Centered Strategies (28%), and Teacher-Centered Strategies (16%). The results reveal that Task-Centered Strategies were the preferred and most used instructional method among the SMEs. The findings align with the literature, emphasizing the importance of hands-on and task-oriented approaches in teaching strategies. Task-Centered Strategies support effective planning for student learning and take into consideration diverse learning methods (Abulhul, 2021; Ravindra, 2018).

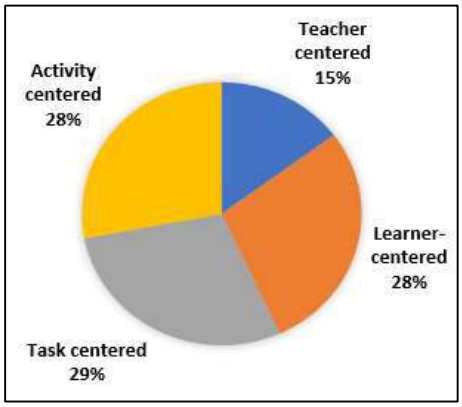

Figure 6: Teaching strategy

The findings from the Rank Analysis presented in Figure 7 highlight that among the SMEs, presentation techniques were the most favored instructional approach, receiving the highest preference from SMEs at 27%. This is followed by discussion techniques at 25%, case study techniques at 21%, debate techniques at 14%, and report techniques at 13%. The SMEs' preference for presentation techniques aligns with the recognition of presentations as a crucial tool for enhancing students' communication skills and preparing them for public speaking (Jones, 2019). Effective communication skills, including oral, written, and listening abilities, are highly valued by employers in today's job market (Santoro & O'Brien, 2020). Therefore, it is essential for students to have ample opportunities to develop and refine these skills during their education.

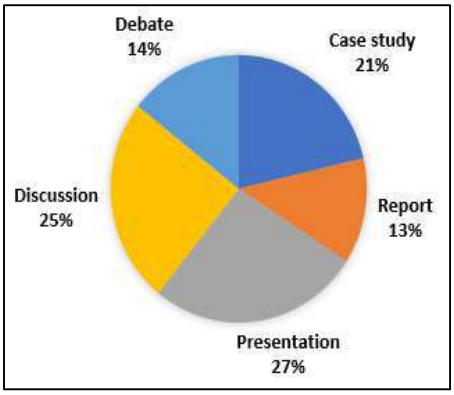

Figure 7: Teaching technique

According to the Rank Analysis depicted in Figure 8, the hybrid style was favored by the SMEs with the highest proportion of respondents favoring it (28%), followed closely by the facilitator style (26%). The demonstrator and delegator styles each received a relatively lower proportion of support at 21% and 14% respectively, while the authority style was favored by the smallest proportion of respondents (13%). The SMEs' preference for the hybrid teaching style aligns with the recognition of the importance of combining traditional and modern instructional methodologies to provide a comprehensive and engaging learning experience (Akimenko, 2016). The hybrid style leverages current technologies, such as interactive movies and virtual reality, alongside conventional tactics like group work and lectures, to facilitate dynamic learning (Cosme Jesús et al., 2022).

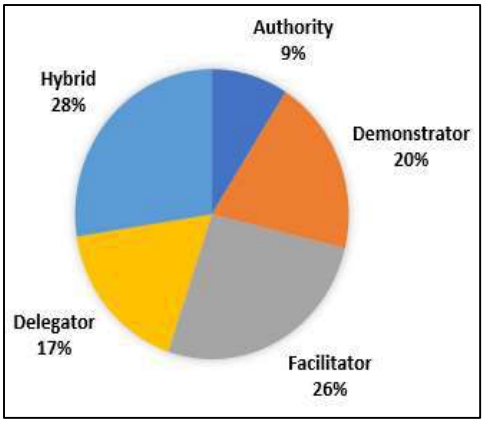

Figure 8: Teaching style

In conclusion, SMEs prefer a blend of integrative, flipped, task-based, presentation-focused, and hybrid teaching and learning methods, which are believed to improve student performance and participation. The integrative method, flipped method, task-based strategies, and presentation techniques are popular for their holistic, personalized, practical, and communication-focused approach respectively. The hybrid style combines traditional and modern methods, utilizing technology for enhanced learning. These findings highlight the need for a blended approach in higher education to provide students with a comprehensive and engaging experience.

Findings and discussion on learning content development

The research findings provide evidence in favor of utilizing the Waterfall Model for the development of educational materials, specifically within the context of the MIS subject. Figures 9 and 10 show how adding visually appealing examples to the UI can increase student engagement and focus, and encourage interactive and participative learning. The teaching resources also include resources for independent study and self-directed learning. Evaluation of students enrolled in MIS subjects at IUKL before and after the implementation of ICT teaching for one semester revealed a 75% improvement in various learning outcomes, including increased engagement in the classroom, increased interest in independent subject exploration, motivation to do project assignments, and finally, better evaluation results.

The Waterfall Model ensures a systematic approach to the development of effective learning content, as highlighted by Singleton and Charlton (2019). This study adopted this strategy, starting with a needs analysis through a detailed literature review and a questionnaire to identify the difficulties faced by SMEs in the MIS course. The learning management system Moodle, which is well known for its collaborative learning capabilities, was used by the researchers to put this paradigm into practise (Addhiny, 2022). Moreover, the incorporation of H5P interactive content into Moodle made it easier to produce and disseminate interactive multimedia learning resources, including presentations, tests, and games (Mir et al., 2021; Hanif et al., 2019).

Figure 9: User Interface

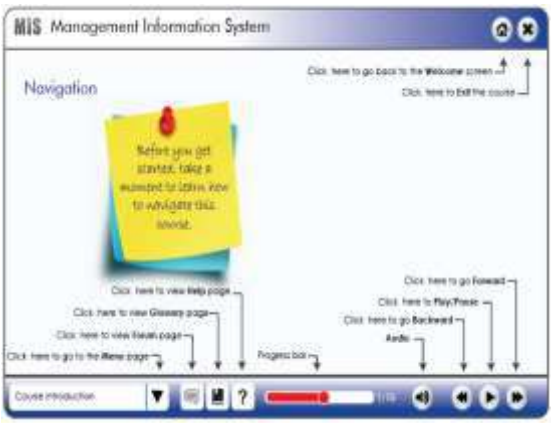

Figure 10: Functions for self-directed learning

The adoption of Moodle and H5P in the development of teaching materials for the MIS subjects aligns with the findings of the literature review, emphasizing the advantages and effectiveness of these tools. The integration of visually appealing examples increases student engagement and encourages collaborative and participatory learning experiences in the UI (Mir et al., 2021). Additionally, Moodle and H5P provide tools for independent study and self-directed learning, giving students the freedom to research a topic independently and create project assignments (Nasrulloh et al., 2018).

In conclusion, the findings of this study affirm the successful implementation of the Waterfall Model, Moodle, and H5P in the development of effective teaching materials for the MIS subjects. The use of these tools and approaches to improve student learning outcomes through aesthetically pleasing interfaces, interactive information, and the promotion of self-directed learning is supported by the alignment between the research findings and the literature review.

CONCLUSION

The study results have shown that integrative approaches, flip methods, task-centered strategies, presentation techniques, and hybrid styles are prioritised by SMEs while delivering interactive visual content for Information Systems courses at the master's level. The considerations above need to be incorporated into developing interactive visual content to boost students' overall performance in Information Systems courses. Due to this, interactive visual content was generated using ePUB and H5P-HTML5 digital tools and then uploaded into the Moodle Learning Management System. Moodle gives educators access to a wide range of resources as well as supplemental exercises and games, which they can use to improve their students' educational experiences. This research is highly pertinent to digitisation and IR 4.0, which aims to produce intelligent and technologically competent communities.

For future development, the input of multiple experts on this research could be developed into an adaptive structure and contents for MIS teaching and assessment methods. A successful trial is already tested at the pilot site for an MIS subject. But this content delivery may be applied in the same subject offered to the public in an e-learning platform. Both these are in demand now as IT/S skills are essential for work to be always competitive. From this foundation, templates for MIS online courses can be developed, or it may also be expanded for any IT/S management courses. Some educators may require training for creating and selling their courses, and this can be considered as a commercialization effort too. We also believe that this template may be used to develop micro-credential courses for the public to upgrade their work and life skills.

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International Journal of Infrastructure Research and Management
Vol. 11 (1), June, 2023, pp. 53 - 68

COMPUTATIONAL FLUID DYNAMICS (CFD) STUDY OF FLOW DEVELOPMENT IN CONCENTRIC ANNULUS AND ECCENTRIC ANNULUS USING TAGUCHI METHOD

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ABSTRACT

Computational Fluid Dynamics (CFD) provides an alternative approach to study about fluid flow in various complex geometries, providing options through the simulations and allowing an alternative form for theoretical advances. The purpose of this study is to find out how the type of flow and the type of annulus affects the overall output. The objectives of this study are to study the fluid flow behaviour with different annulus geometries and investigate the optimum effect of different flow regimes with dissimilar annular passages on velocity profiles using the Taguchi method. In this study, a series of simulations are done for fully developed laminar flow and turbulent flow in different annulus geometry and observed the flow behaviour in the annulus. The factors used in the simulations are flow regime and annulus geometry. It is found that the flow development in the concentric annulus is uniform but non-uniform in the eccentric annulus. The concentric annulus with laminar flow combination gave the lowest maximum velocity, which is 0.0989 m/s at the outlet of the annulus, while the eccentric annulus with turbulent flow combination gave the highest maximum velocity of 2.246 m/s. Through the analysis of the Taguchi method and ANOVA technique, the combination of the eccentric annulus and turbulent flow showed the highest fluid flow velocity with flow regime being the most significant factor (P-value of 0.011) based on the significant value (P-value less than 0.05 is statistically significant). The investigation through the Design of Experiment (DOE) and ANOVA technique should provide the reference for future studies in effectively identifying the effect of other factors such as the annulus design and the operating condition of the cylinders. The suggestions for future studies include studying the effect of drilling mud as the type of fluid and studying the effect of inner shaft rotation on the output by using DOE strategies.

Keywords:
CFD, Fluid Flows, Concentric and Eccentric Annuli, Taguchi Methodology, ANOVA

INTRODUCTION

The study of fluid flow is significantly important in various fields such as the oil and gas industry when engineers deal with Newtonian and non-Newtonian fluids in the eccentric annulus or concentric annulus. The eccentricity of an annulus is the amount of displacement of a geometric centre of a rotating or non-rotating part from the true centre. The eccentric annulus will have the same cross-sectional area as the concentric annulus but a different fluid flow profile. A 0.0 pipe eccentricity means that the inner part is perfectly centred in the annulus (100% casing standoff). Vice versa, an eccentricity of 1.0 means that the inner part is in close contact with the annulus (0% casing standoff).

Annular flow performance is vital to be studied as it significantly affects the planning and design of the hydraulic program for a well-drilling operation (Mohammed Nawai, 2011). This is due to pressure may be lost at a major scale in a constricted space. An eccentric annulus will have a lesser frictional pressure drop than a concentric annulus as the gap is wider on one side for fluid to flow. Higher eccentricity allows fluid to flow with lesser energy required. A concentric annulus will have a uniform axial velocity profile, while an eccentric annulus will have a slower fluid flow narrow side of the pipe, which may cause a problem like solid accumulation if not appropriately studied.

One of the major challenges in designing a hydraulic program is to precisely estimate the pressure drop of drilling fluid due to friction in a wellbore annulus. Several parameters cause frictional pressure losses of the drilling fluid, such as the rheology of the drilling fluid, flow regime and pipe

eccentricity (Mohammed Nawai, 2011). Problems like overestimating pressure drops will occur if the pipe eccentricity is not considered during the designing of the program as eccentric annulus will decrease the frictional pressure losses considerably.

In a well-drilling operation, it is crucial for frictional pressure loss calculations as the calculation allows the determination of horsepower required to operate the drill. The frictional pressure loss calculation will also be used to determine the bottom hole treating pressure and maximum wellbore pressure. Optimising the drilling parameter through the calculation allows engineers to make an applicable evaluation of wellbore hydraulics. It will reduce drilling problems encountered and at the same time, reduce drilling operation costs.

The velocity of fluid flow in different geometries is studied. The concentric annulus and eccentric annulus are studied through the simulation by using Computational Fluid Dynamics (CFD) method in ANSYS Fluent, where the meshing of the annulus is conducted. ANSYS is one of the software used for finite element analysis (FEA) other than ABAQUS and DIANA. According to Zhicheng and Nordin (2022), ANSYS is less employed in papers published in recent years than ABAQUS. Thus, the selection of ANSYS software in the research may further contribute to the FEA study's coverage of the software application. Taguchi method is used to study the effect of different fluid flow regimes (laminar flow and turbulent flow) in different geometries. The simulation runs are set according to the Orthogonal Array Design in the Taguchi method and the data is analysed by using the ANOVA technique with the aid of Minitab software.

Problem Statement

One of the downsides of drilling horizontal and inclined wells is that wellbore eccentricity will occur due to the inclination (Kelessidis & Dukler, 1989). The eccentric annulus differs from the concentric annulus as the inner part is offset to one side of the annulus. The eccentric annulus will have a non-uniform fluid velocity profile. The stagnant zone in the eccentric annulus due to low fluid flow velocity causes the cutting removal process during the drilling operation to be inefficient. The pressure losses in an eccentric annulus are only 40% of the value in a concentric annulus. From an industrial application standpoint, the issue regarding fluid flow in the annular space between two circular cylinders is still encountered in many types of equipment and engineering applications due to a narrow annular space that exists in the clearance (Abou-Ziyan et al., 2021). Well-drilling (the annulus between a borehole and a drill pipe), as well as mixers and heat exchangers, are among the involved equipment as they are based on the same annulus design. Therefore, the similar flow behaviour of fluid in a concentric annulus cannot be implemented in an eccentric annulus. The flow simulation using Computational fluid dynamics (CFD) modelling is required to study this matter.

Due to the geometry of the concentric annulus and eccentric annulus being different, approximation of the flow regime in both the concentric annulus and eccentric annulus may be inaccurate in the calculation of heat transfer in designing the drilling program. Hence, many studies do not actually provide a solution as nearly all analysis focuses on only one type of flow regime on a specific geometry. Besides, a good hole cleaning allows the operation to avoid drilling issues. If the hole cleaning is failed to be ensured, major costly drilling problems such as cutting bed formation damage, fluid loss, lost circulation, high torque and drag, or stuck pipe may occur, where the cost may be up to millions of dollars to be covered by the company. Therefore, this study focused on the type of flow regime (laminar flow and turbulence flow) in affecting the velocity profile in both the concentric annulus and eccentric annulus.

Research Objectives

As fluids behave differently in the concentric annular passage and eccentric annular passage, it is important to study the effect of different geometries on fluid flow development. This study is conducted by using Computational Fluid Dynamics (CFD) method.

The flow regime in an annular passage can be laminar flow or turbulent flow, thus it is important to study different types of flow regimes in a different type of annulus. The effect of flow regime on velocity profiles is focused in this study as well.

The objectives of this study are to study the fluid flow behaviour with different annulus geometries using Computational Fluid Dynamics (CFD) and to investigate the optimum effect of different flow regimes with dissimilar annular passages on velocity profiles using the Taguchi Method.

LITERATURE REVIEW

Singh et al. (2021) conducted a CFD analysis on the turbulent flow of power-law fluid in a partially blocked eccentric annulus. They aim to study the turbulent flow of power-law fluid in wellbores and develop a relationship between bed shear stress and the level of blockage. When the blockage level of an annulus increases, the local fluid velocity and cutting bed shear stress are reduced. A series of simulations and analyses found that the bed height, diameter ratio, and fluid behaviour index will eventually affect the dimensionless bed shear stress, which is one of the crucial flow parameters. Besides, the authors stated that the thickness of the cutting bed would affect the annular pressure gradient, which is more noticeable when the dimensionless bed height is greater than 50%. Lastly, the authors used CFD simulation of turbulent flow in this study because CFD simulation provides a satisfactory projection of relevant flow parameters.

Ferroudji et al. (2019) did a numerical study on power-law fluid flowing through the concentric annulus and eccentric annulus using the finite volume method under the conditions of both laminar flow regime and turbulent flow regime with inner shaft rotation. The purpose of the study is to find out the effect of inner rotation on pressure drop in the concentric annulus and eccentric annulus under both types of flow regimes. The study also focused on the variation of flow behaviour index and diameter ratio from low to high values that affects the pressure drop. The study showed that the inner shaft rotation successfully reduces the pressure drop in a concentric annulus, but the effect is negligible if the flow regime is turbulent. The formation of secondary flow will increase the pressure drop slightly for both laminar and turbulent flow. The increase of the flow behaviour index and diameter ratio from a low to a high value will result in a higher pressure drop. They found out that to prevent secondary flow from forming, a low diameter ratio and high flow behaviour index of the eccentric annulus are needed.

Escudier et al. (2000) did a similar study that focus on the effects of inner cylinder rotation on the laminar flow of a Newtonian fluid through an eccentric annulus. The study carried out by Escudier et al. (2000) focuses on the fully developed laminar flow of a Newtonian liquid through an eccentric annulus with combined bulk axial flow and inner cylinder rotation. The flow behaviour in the annulus is analysed by the low, medium, and high eccentricity of the annulus. For low eccentricity ($E < 0.3$) annulus, the flow is rotation dominated. This means that the Fanning friction factor and Reynolds number may increase higher than the value of the non-rotating inner shaft concentric annulus. This is due to the flow being pulled around the inner shaft transferring the peak velocity in the wide gap to the narrow gap, which increases the axial gradient. As for medium eccentricity ($0.3 < E < 0.8$) annulus, the study showed that friction is reduced when eccentricity increases, resulting in a lower frictional pressure drop. However, secondary flow begins to develop, having the maximum axial velocity in the wide gap of the annulus. Lastly, for high eccentricity ($0.8 < E < 1$) annulus, the

flow is recirculation dominant, but the authors observed an unexpected flow behaviour. The location of peak velocity is transferred into the widening gap region due to the stronger recirculation. When the flow moved towards the recirculating eddy, it is forced towards the "lower" surface of the inner cylinder, which produces high localised shear stress in the annulus. This reduces the Fanning friction factor and Reynolds number with eccentricity and then further prompts an increase.

Neto et al. (2011) conducted a study on the turbulent flow in the concentric and eccentric annulus with a rotating inner shaft by using Laser Doppler Velocimeter (LDV) technique to get the axial, radial, and tangential mean velocity profiles. By using ANSYS Fluent, the authors managed to carry out a simulation and obtained results with low relative errors. Contours of velocities in an eccentric annulus are included in the study to show the area of the maximum velocity of fluid flow in an eccentric annulus and how the inner rotating shaft affects the fluid flow. The authors used five (5) different turbulent models in the simulation and obtained simulation results that are close to each other. The authors claimed that the flow velocity in the narrow part of the eccentric annulus is much lower than the flow velocity in the wide part of an annulus with a non-rotating inner shaft, which means that cutting beds are easily deposited in the narrow gap of the eccentric annulus. In this study, they showed that the rotating inner shaft aids in preventing cutting bed deposition as the fluid flow is dragged towards the narrow gap of the eccentric annulus, which is similar to what Escudier et al. (2000) obtained from their study for low eccentricity ($E < 0.3$) annulus.

In the recent review summarized by Abou-Ziyan et al. (2021), they tabulated the fluid flow work for concentric and eccentric studies and indicate that this work still receives a major consideration. This includes the study of laminar flow, turbulent flow, stationary inner cylinder and rotating inner cylinder with various radius ratios. Further from the recent research findings, the effect of rotation on the annular space of radii ratios is still lacking in the literature where it becomes the interest in industrial applications including rotating heat exchangers, mixers, agitators and well drilling to work more efficiently (Abou-Ziyan et al., 2021). The study on the effect of radius ratio on eccentricity still needs to be investigated. In addition to the literature summarized by Abou-Ziyan et al. (2021), the author reviewed that various factors could lead to different findings such as the maximum axial velocity impacted by a different annulus, radius ratio, fluid properties and flow characteristics. These factors should be properly studied with a better approach in designing the experimental or simulation run without relying too much on a trial-and-error approach for optimum results. For this purpose, a Design of Experiment (DOE) methodology that emphasizes statistical analysis such as the Taguchi Robust Methodology should be applied.

Reynolds Number Equation

The higher the Reynolds number of a fluid type, the more turbulent the fluid is. If the fluid has a Reynolds number below 2100, the fluid flow is laminar. In the other hand, if the Reynolds number is more than 4000, the fluid flow is turbulent. If the Reynolds number is between 2100 and 4000, the fluid flow is considered transition flow. The Reynolds number can be determined by using the formula shown below:

$$Re = \frac{\rho v D}{\mu} \tag{1}$$

Where, Re = Reynolds number, ρ = Density of fluid, v = Velocity of fluid flow through the pipe, D = Diameter of pipe (also referred to as hydraulic diameter, dh) , μ = Dynamic viscosity of the fluid

Taguchi Method and Analysis of Variance (ANOVA)

Taguchi method is also known as Taguchi design, which is a designed experiment that allows the choice of factors that function consistently in an actual operating environment (Minitab, 2021). Not every factor can be controlled; thus, these factors are known as noise factors. By using the Taguchi method, control factors are identified, and noise factors are minimised. A process output with the least noise factors will produce a consistent output and performance regardless of environmental conditions.

Taguchi method uses orthogonal arrays, which is a combination of factors to estimate the effects of factors on the response mean and variation. An orthogonal array produces a balanced design in that all factor levels are equally weighted. Due to the orthogonal array design, each factor is assessed independently so that one factor does not affect the approximation of a different factor.

Figure 2 shows an example of an orthogonal array design, which is $L_8(2)^7$. The L_8 in the orthogonal array means that there are eight runs to be conducted, and $(2)^7$ means that there are seven factors with two levels per factor. As previously mentioned, the orthogonal array has all the factor levels equally weighted. The table columns are the control factors, and the table rows are the number of run, which is the combination of factors. The numbers in the table represent the factor levels to be used in the experiment or simulation.

Analysis of variance (ANOVA) is the method to evaluate the importance of factors by comparing the responding variable means at different factor levels (Minitab, 2021). Executing the ANOVA technique requires one responding variable and at least 1 factor with two or more levels. ANOVA requires data that are almost normally distributed to populations with equal variance between factor levels. ANOVA is the approach where variances are used to determine whether the means are different.

Orthogonal Array	Number of Runs	Maximum Factors	Maximum of columns at these levels			
			2-level	3-level	4-level	5-level
L4	4	3	3			
L8	8	7	7			
L9	9	4		4		
L12	12	11	11			
L16	16	15	15			
L'16	16	5			5	
L18	18	8	1	7		
L25	25	6				6
L27	27	13		13		
L32	32	31	31			
L'32	32	10	1		9	
L36	36	23	11	12		
L'36	36	16	3	13		
L50	50	12	1			11
L54	54	26	1	25		
L64	64	63	63			
L'64	64	21			21	
L81	81	40		40		

Figure 1: Taguchi Orthogonal Arrays Selection Table Based on Factors (Balisnomo, 2008)

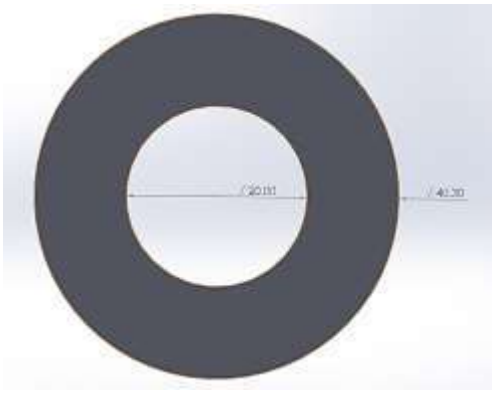
	A	B	C	D	E	F	G
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

Figure 2: Example of $L_8(2)^7$ Orthogonal Array

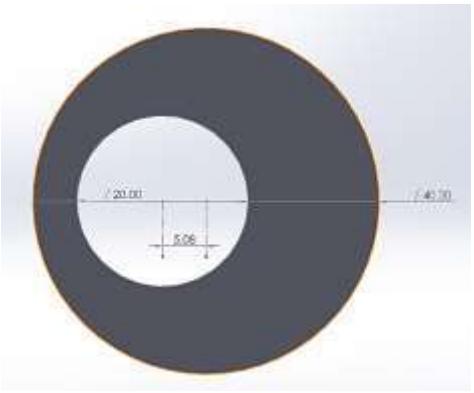
METHODOLOGY

As the first objective of this study is to study the fluid flow behaviour in different annulus geometries, the simulation used the same velocity and geometry parameter (dimension) to observe the development of flow in the different annulus. In this case, the fluid used in the simulation is water as water is a Newtonian fluid and in most drilling operations, water or drilling mud is used as the drilling fluid due to high heat capacity. The water is assumed to be in the condition of no heat generation, no-slip condition, and steady-state fluid. The density of the fluid (ρ) is 998.2 kg/m3, dynamic viscosity (μ) of 0.001003 kg/ms, specific heat capacity (C_p) of 4.182 kJ/kg·K and thermal conductivity of 0.6 W/m·K.

The length of pipe for both the concentric annulus and eccentric annulus is set to constant to determine the variation of results obtained in the simulation. The dimension for geometries in the present simulation work is selected based on the geometry used by Mohammed Nawai (2011) and Neto et al. (2011). According to Neto et al. (2011), the dimension of the annulus was extracted from the previous experimental parameters for concentric and eccentric annular gaps studied by Nouri & Whitelaw (1994). The outer diameter of the pipe (*do*) is 40.3 mm, while the inner diameter of the pipe (*di*) is 20 mm. The eccentricity of the concentric annulus is E = 0.0, while the eccentricity of the eccentric annulus is E = 0.5. As the hydraulic diameter (*dh*) equals to the outer diameter of the pipe minus the inner diameter of the pipe (*dh = do – di*), hence the hydraulic diameter of the pipe in this study is 20.3 mm. The computational length of the pipe is 101 mm. The drawing of the annulus is made by using Solidworks software. All units of the drawing are in millimetre (mm) units. The schematic diagram of the concentric and eccentric annuli with dimensions are shown in Figure 3 (a) and Figure 3 (b) respectively.



(a): Concentric Annulus



(b): Eccentric Annulus

Figure 3: Schematic diagram of (a) Concentric Annulus, (b) Eccentric Annulus

The meshing of the annulus is an important factor in conducting CFD analysis as it improves the accuracy of the simulation. The meshing of the annulus is conducted before the simulation in ANSYS Fluent by importing the Solidworks annulus drawings into the software. By referring to references, the annulus meshing is done using Patch Conforming Method to mesh the geometry. The element of the meshing is Tetrahedron type. The body mesh sizing is 1.5×10^{-3} m, while the geometry faces mesh with sizing of 5×10^{-4} m, which is smaller than body sizing, to improve the accuracy of the simulation.

To study the effect of different flow regimes with dissimilar annular passages on velocity profile, laminar flow regimes and turbulent flow regimes are used in the simulation. The Reynolds number of the laminar flow regime is set to 1600 (Re = 1600), while the turbulent flow regime Reynolds number is set to 43234 (Re = 43234). For laminar flow simulation runs, the Reynolds number is set to 1600, and the inlet velocity is calculated by using Eqn (1) together with water properties, giving us an inlet velocity of 0.0792 m/s. The inlet velocity for turbulent flow simulation runs is maintained at 2.14 m/s, which is the same inlet velocity as the reference. Using 2.14 m/s inlet velocity, the Reynolds number for turbulent flow simulation runs is calculated using Eqn (1) as well together with properties of water to obtain the Reynolds number for turbulent flow simulation runs of 43234. The turbulent model of the k-ε Standard is selected for the simulation. The simulation is carried out by using ANSYS Fluent software.

For the Taguchi design of this simulation, there are two factors with two levels in conducting the simulation. The orthogonal array in this study is $L_4(2)^2$. The first factor is the flow regime. The two levels of the first factor (flow regime) are laminar flow and turbulent flow. The second factor is the geometry of the annulus. The two levels of the second factor (annulus geometry) are concentric annulus and eccentric annulus. The orthogonal array used in this study is presented in the table below. The Taguchi design analysis is carried out using Minitab software to analyse the S/N ratio. ANOVA technique is used to analyse the factors by plotting means to determine the most affecting factor and ranking the factors in this simulation.

Table 1: $L_4(2)^2$ Orthogonal Array

Trial Number	Flow Regime	Annulus Geometry
1	1	1
2	1	2
3	2	1
4	2	2

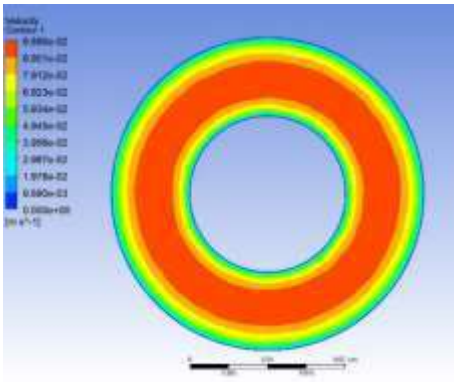
Table 2: Factors with Chosen Levels

Factors	Level of Factors	
	1	2
Flow Regime	Laminar Flow	Turbulent Flow
Annulus Geometry	Concentric Annulus	Eccentric Annulus
Note: Flow Regime:- Level 1 (Laminar Flow, Re = 1600), Level 2 (Turbulent Flow, Re = 43234)		

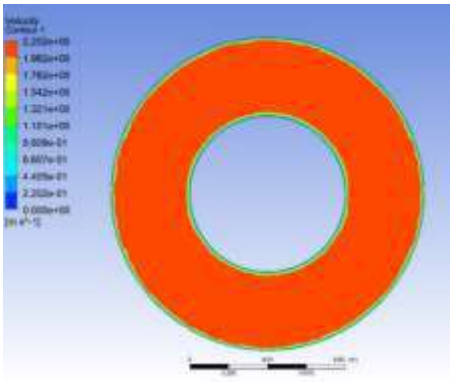
It is important to be highlighted that this study focuses on studying the effect of different Re with a different flow regime on the axial velocity without the rotating condition. The Taguchi method is used in designing the trial combinations and the flow results are then analysed to select the optimum parameters based on the highest S/N ratio (Larger-the-Better). The data is further analysed by using ANOVA to statistically identify the most significant factor that affects the response based on the significant value (P-value). These steps are important at this early stage to set the reference for future testing with more factors and conditions.

RESULTS AND DISCUSSION

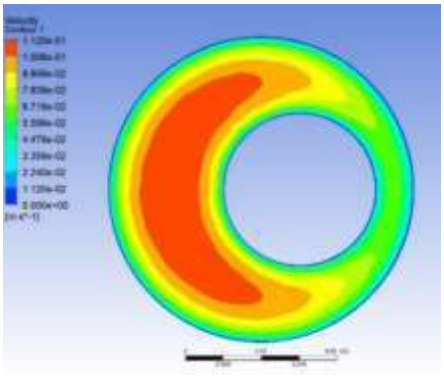
The colours in the velocity contour represent different fluid flow magnitudes. The blue colour contour around the annulus wall shows that the velocity at that location is zero. This is due to the internal resistance of fluid flow, in other words, no-slip condition around the wall. Through the analysis of four simulation runs, it is proven that fluid flow velocity is not uniform when flowing through any surface. Simultaneously, any fluid will have zero velocity at the solid surface due to the no-slip condition. However, the fluid layer that flows far from the solid surface will eventually reach free stream velocity and shows a red-coloured contour in the velocity contour. As shown in Figure 4(a), Figure 4(b), Figure 4(c), and Figure 4(d), the high-velocity magnitude flow shows a red contour, while the flow around annulus walls shows a blue contour.



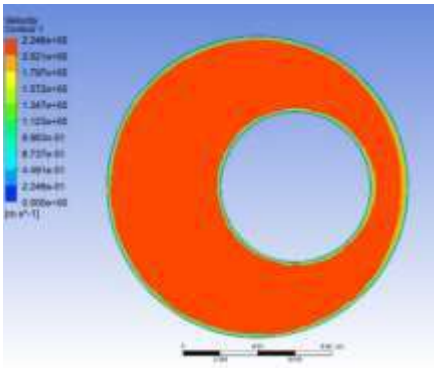
(a) Laminar Flow + Concentric Annulus



(c) Turbulent Flow + Concentric Annulus



(b) Laminar Flow + Eccentric Annulus



(d) Turbulent Flow + Eccentric Annulu

Figure 4: Velocity Contour of (a) Laminar Flow + Concentric Annulus combination, (b) Laminar Flow + Eccentric Annulus combination, (c) Turbulent Flow + Concentric Annulus combination, (d) Turbulent Flow + Eccentric Annulus combination

Dynamic pressure is the pressure produced by the flowing of fluids. Theoretically, dynamic pressure is higher when the fluid flow velocity is high than in slow-flowing fluids with constant fluid density. In this case, the dynamic pressure is linearly proportional to fluid flow velocity. The relationship between dynamic pressure and fluid velocity is proved in Figure 5(a) and Figure 5(b). In Figure 5(a), the walls of the concentric annulus are positioned at around -0.02 m, -0.01 m, 0.01 m, and 0.02 m. It is observed that the velocity magnitude reduces around the wall of the annulus due to the no-slip condition. Comparing with Figure 5(b), it is observed that the dynamic pressure drops at the same location, which are the walls of the annulus, proving that the dynamic pressure is linearly proportional to the velocity magnitude of flow. This phenomenon is observed to be the same even if the flow regime is turbulent flow, which is proven in Figures 6(a) and 6(b). Besides, based on the graphs obtained through simulation, it is observed that the fluid flow across concentric annulus annular passage is uniform.

Due to the higher fluid inlet velocity used in turbulent flow regime simulation runs, the resulting velocity magnitude in the annulus is much higher compared to laminar flow regime simulation runs. This is due to the higher Reynolds number used in turbulent flow regime simulation runs. As dynamic pressure is linear to velocity magnitude, the dynamic pressure in the annular passage for turbulent flow regime simulation runs is much higher than laminar flow regime simulation runs.

In the case of eccentric annulus simulation runs, it is also observed that the velocity magnitude reduces around the wall of the annulus due to the no-slip condition and the dynamic pressure drops at the same location. However, due to the smaller gap on one side of the eccentric annulus, the fluid flow velocity of the smaller gap is lower than the large gap of the annulus. The lower fluid flow velocity results in lower dynamic pressure as well. This indicates that the fluid in the smaller gap has a lesser ability to carry any solid particles in terms of the drag force applied on the particles, which may cause solid formation and result in annulus blockage. Based on CFD simulation by Hajipour (2020) on the drill cuttings and parametric studies on the eccentric annulus, the effect of particle size on hole cleaning is more obvious at higher drilling fluid flow velocity. The concentration for all particle sizes is transferred easily in the annulus with the increase of drilling fluid flow rate which also causes higher drag force exerted on the solid particles. This issue also happens when the turbulent flow regime is used in the simulation run but with higher fluid flow velocity and dynamic pressure values. The simulation results show that the flow experiences higher pressure losses in the narrow gap of eccentric annulus due to the flow resistance between the gaps.

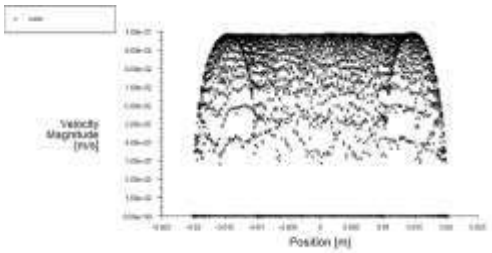


Figure 5 (a): Graph of Velocity Magnitude versus Annulus Position (Laminar Flow + Concentric Annulus)

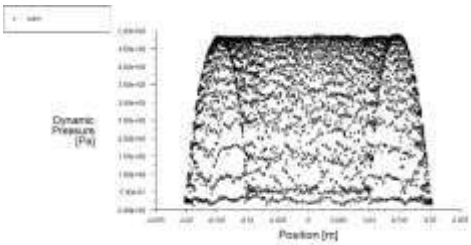


Figure 5 (b): Graph of Dynamic Pressure versus Annulus Position (Laminar Flow + Concentric Annulus)

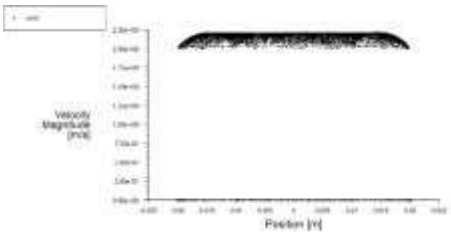


Figure 6 (a): Graph of Velocity Magnitude versus Annulus Position (Turbulent Flow + Concentric Annulus)

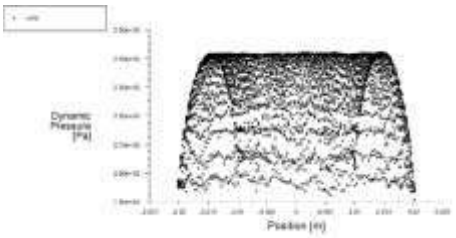


Figure 6 (b): Graph of Dynamic Pressure versus Annulus Position (Turbulent Flow + Concentric Annulus)

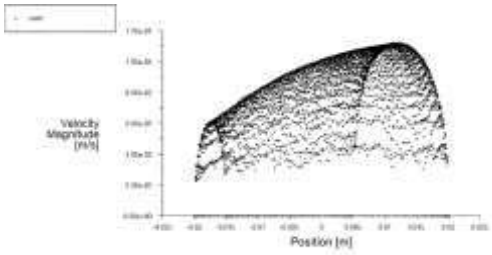


Figure 7 (a): Graph of Velocity Magnitude versus Annulus Position (Laminar Flow + Eccentric Annulus)

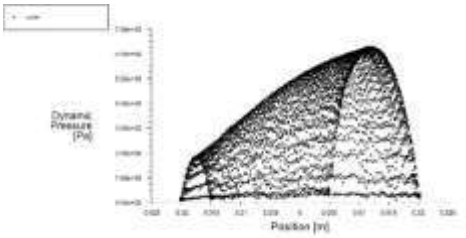


Figure 7 (b): Graph of Dynamic Pressure versus Annulus Position (Laminar Flow + Eccentric Annulus)

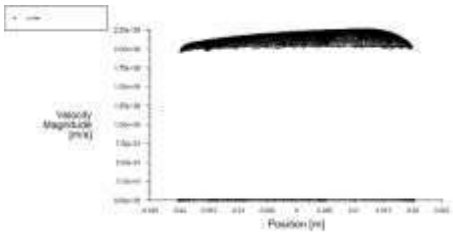


Figure 8 (a): Graph of Velocity Magnitude versus Annulus Position (Turbulent Flow + Eccentric Annulus)

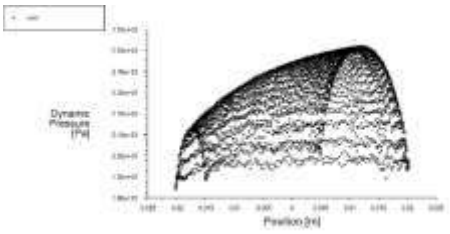


Figure 8 (b): Graph of Dynamic Pressure versus Annulus Position (Turbulent Flow + Eccentric Annulus)

Based on the simulation results, the maximum velocity of fluid flow in each simulation runs are recorded based on the generated velocity contour. From the results, the maximum velocity of each simulation run is tabulated in Table 3.

Table 3: Maximum Velocity at Outlet for Each Simulation Run

Trial Number	Flow Regime	Annulus Geometry	Max Velocity
1	1	1	0.0989 m/s
2	1	2	0.112 m/s
3	2	1	2.202 m/s
4	2	2	2.246 m/s

Model comparison

The prediction of the CFD model is compared against results reported by Mohammad Nawai (2011) for the validation of concentric and eccentric annuli with the eccentricity, E of 0.0 and 0.5 respectively. The radius ratios, η for both present and Mohammad Nawai (2011) models are 0.5. A comparable result is obtained for Re 1600 where the axial velocity for the smaller gap in the eccentric annulus decreases in contrast with the concentric case. This is mainly the slight percentage of water flows in the small space due to a larger resistance to flow than that of the wider gap (Abou-Ziyan et al.,2021; Neto et al.,2011). The other comparison is made to the axial velocity of the concentric

annulus where the velocity distribution is approximately symmetry, and the maximum axial velocity is near the centre of the cross-sectional hydraulic area (r/s = 0.5). X-axis (r/s) is the distance between the inner and outer cylinder with 0.0 at the outer cylinder surface and 1.0 at the inner cylinder surface. For a higher Re, a reasonable agreement in the velocity distribution is obtained for Re over than 2000 (Re > 2000) to that of the result of the stationary inner cylinder by Abou-Ziyan et al. (2021).

Analysis of Variance (ANOVA)

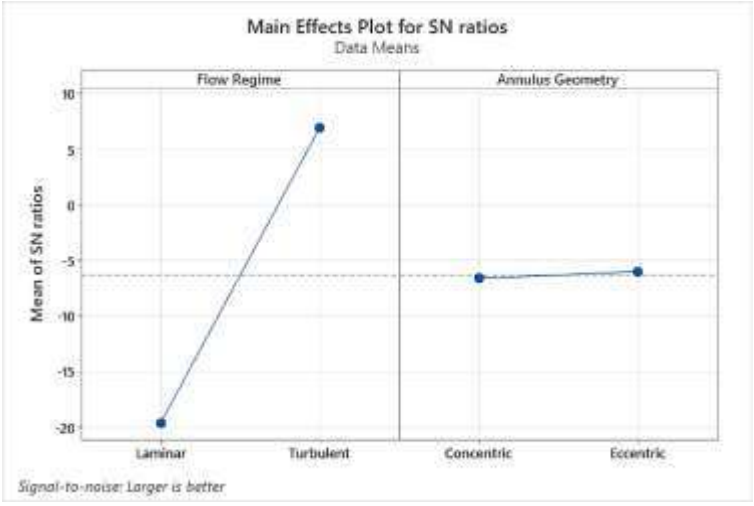


Figure 9 (a): Main Effects Plot for S/N Ratios for Flow Regime and Annulus Geometry

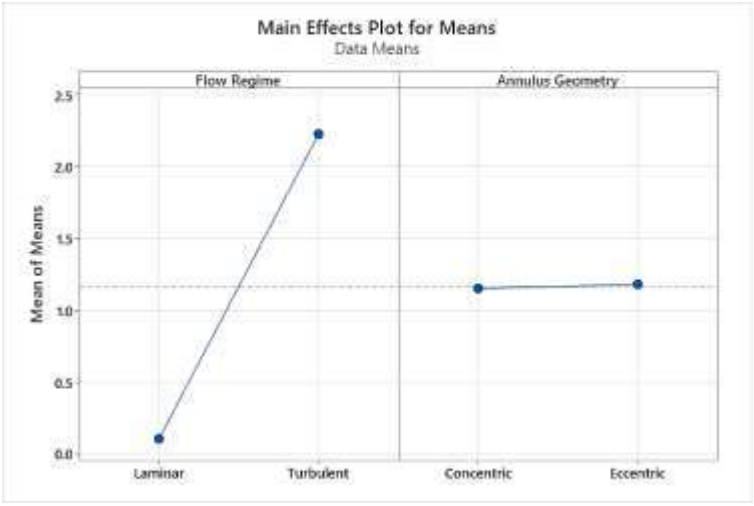


Figure 9 (b): Main Effects Plot for Means for Flow regime and Annulus Geomet

Table 4: S/N Ratio Results

Factors	Levels	S/N Ratio
Flow Regime	1	-19.5559
	2	6.94227
Annulus Geometry	1	-6.61986
	2	-5.99372
Note: Flow Regime:- Level 1 (Laminar Flow, Re = 1600), Level 2 (Turbulent Flow, Re = 43234) Annulus Geometry:- Level 1 (Concentric Annulus), Level 2 (Eccentric Annulus)		

Table 5: Results of ANOVA

Factors	Sum of Square (SS)	Total Sum of Square (Total SS)	Contribution	P-value
Flow Regime	702.151	702.749	99.9149 %	0.011
Annulus Geometry	0.392	702.749	0.0558 %	0.400

Table 6: Response Table for S/N Ratios

Level	Flow Regime	Annulus Geometry
1	-19.556	-6.620
2	6.942	-5.994
Delta	26.498	0.626
Rank	1	2
Note: Flow Regime:- Level 1 (Laminar Flow, Re = 1600), Level 2 (Turbulent Flow, Re = 43234) Annulus Geometry:- Level 1 (Concentric Annulus), Level 2 (Eccentric Annulus)		

Table 7: Prediction of Response Value using Optimum Parameters

Optimum parameter:		Actual Max Velocity	Predicted Max Velocity	Error (%)
Flow Regime	Turbulent Flow	2.2460	2.23828	0.3437
Annulus Geometry	Eccentric Annulus			
Note: Turbulent Flow, Re = 43234				

Table 4 shows the S/N ratio for each factor with respective levels computed in the Taguchi process based on the outcome of Table 3. From Table 4, the combination of the maximum S/N ratio from each factor level will result in the best outcome of the experiment due to the larger the S/N ratio, the better the response value we obtained. The S/N ratio graph shows the graphical representation of response variable change as a function of influencing factor level variation. Figure 9 (a) shows the S/N ratio response curve of this Taguchi experiment. Figure 9 (b) shows the trend of fluid flow velocity, where the velocity increases when the flow regime is turbulent flow, and the annulus geometry is the eccentric annulus.

Based on Figure 9 (a), the highest point of each S/N ratio graph is located at Turbulent Flow and Eccentric Annulus for the 'flow regime' factor and 'annulus geometry' factor, respectively. There is a large variation between the two points for the 'flow regime' factor graph, but the variation is small for the 'annulus geometry' graph. However, both graphs show a constant trend where the S/N ratio increases when the factor level is level two, which is Turbulent Flow and Eccentric Annulus. This indicates that turbulent flow and eccentric annulus will result in the highest velocity at the outlet. When the flow regime is turbulent, the high Reynolds number also results in high fluid flow velocity. Dynamic pressure increases simultaneously due to higher fluid flow velocity. The high dynamic pressure allows fluid to carry more solids during the flow, which removes the bed cuttings from the annular passage. Eccentric annulus aids in providing higher outlet velocity as well due to the wide gap on one side of the annulus. The flow friction in the eccentric annulus is reduced when eccentricity increases, resulting in a lower frictional pressure drop (Escudier et al., 2000). However, the downside of the eccentric annulus is that solid bed formation may occur at the narrow gap due to lower fluid flow velocity than in the wide part of the annulus with a non-rotating inner shaft. According to a previous study, the solution to prevent solid bed deformation is to use a rotating inner shaft. The inner rotating shaft will drag the fluid flow towards the narrow gap of the eccentric annulus (Neto et al., 2011).

In order to determine the effect of factors on the response variable, the ANOVA technique is carried out and results are recorded in Table 5. As shown in Table 5, the contributions in the percentage of flow regime factor and annulus geometry factor are 99.9149% and 0.0558%, respectively. The percentage contribution is to determine which factor significantly affects the maximum velocity of fluid flow in the annular passage. The larger value of the percentage contribution, the greater the influence of the factor on the response variable. The results of ANOVA show that the most influencing factor is the flow regime, which holds 99.9149% of the contribution to the response variable. In other words, the Reynolds number of a fluid affects the maximum velocity. Besides, the flow regime and annulus geometry factors have a P-value of 0.011 and 0.4, respectively. The P-value of the flow regime factor is lower than the significance level of 0.05 (Minitab, 2022; Hamdan & Yusof, 2014), meaning that the flow regime factor is statistically significant to the changes in the response value. As for the annulus geometry factor, it is not statistically significant to the changes in response as the P-value is 0.4, which is higher than 0.05.

Based on the analysis of the S/N ratio graph and the results of the ANOVA technique, it is concluded that the flow regime is the most influencing factor on the maximum velocity of fluid flow in an annular passage. The level of influencing factor can be observed by referring to the rank number in Table 6. This study uses the ranking method to decide the level of influencing factor according to the S/N ratio characteristic based on the Larger-the-Better. The ranking method is a descriptive statistic that ranks the calculated value of the respective factor (Okpala & Roslan, 2019). Turbulent flow has a much higher Reynolds number, which results in higher dynamic pressure. On the other side, an eccentric annulus also contributes to velocity changes due to the wide gap on one side of the annulus, resulting in lower frictional pressure loss compared to a concentric annulus. Figure 9 (b) also shows the main effect of the eccentric annulus on the mean velocity being higher than the concentric annulus. Hence, in this case, the optimum combination for maximum velocity in the annular passage is Turbulent Flow for the 'flow regime' factor and Eccentric Annulus for the 'annulus geometry' factor.

CONCLUSION

The two main objectives of this study are achieved. The concentric annulus has a constant flow development, while the eccentric annulus has non-consistent flow development due to the narrow gap on one side, and it tends to have lower pressure loss towards the inner of the annulus at the wide gap section. This is due to the no-slip condition of the fluid and the resistance of fluid flow between the inner annulus walls decreases. Comparing the wide gap and narrow gap of the eccentric annulus, the fluid flow velocity at the narrow gap is lower. The low fluid flow velocity may result in problems such as solid bed deposition, affecting the overall drilling process. Using the Taguchi method and ANOVA technique, the flow regime factor affects the response value the most, which is the maximum velocity of fluid flow in the annulus. Compared to annulus geometry, the contribution of the flow regime factor is 99.9149%, which is the most significant factor that affects the response value and is ranked number one (1) among the combination of factors. In the four simulation runs, eccentric annulus with turbulent flow results in the highest fluid flow velocity. This shows that the combination of the eccentric annulus with the turbulent flow has a better solid carrying ability due to the higher drag force to be applied on the particles compared to other combinations. This is considered the best combination in this study using water as a fluid. It is important to highlight that this study involves only water. For other types of fluid such as drilling mud, a future investigation must be done to identify its combined effects with the annulus design and cylinder operating conditions.

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International Journal of Infrastructure Research and Management
Vol. 11 (1), June 2023, pp. 69 - 76

DESCRIPTIVE AND CORRELATION ANALYSIS OF IRON AND MANGANESE IN THE RIVERBANK SYSTEM

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ABSTRACT
An increase in river water toxicity and frequent water cuts are major concerns in Malaysia. Riverbank Filtration system (RBF) is a good alternative technology to improve raw water quality. However, high concentration of metals such as Iron (Fe) and manganese (Mn) in RBF is one of the main problems. This study analyses and compares the concentration of Fe and Mn in RBF and the Kerian River water using descriptive statistical analysis and Pearson Correlation analysis. The results show that the mean concentration of Fe and Mn is higher at the RBF pumping well with a mean value of 4.823 mg/l which is 96 % compared to the concentration of Fe in Kerian River (0.1708 mg/l). Meanwhile, Mn concentration in RBF pumping well is 0.1854 mg/l compared to the Kerian River water with Mn concentration of 0.00056 mg/l. The difference in the concentration is approximately 100%. Typically, the concentration of metals or minerals in groundwater is closely related to the type of soil in the area and hydro-geochemical activities in the location. In this study, the results prove that the concentration of Fe and Mn in RBF is higher than surface water which is highly connected to the soil layer in the study location. At the same time, the concentration of these elements in water exceeded the MOH standard for permissible drinking water standard which are Fe = 0.3 mg/l and Mn = 0.1 mg/l. From the Pearson Correlation analysis, it was found that Fe and Mn in both RBF and Kerian River have a strong correlation of ($R > 9.0$) indicating that the existence of Fe and Mn is highly influencing each other. Parameters such as EC, Turbidity, TSS and TDS moderately correlate with Fe and Mn and are within the ranges of ($0.3 < R < 0.7$) demonstrating that there is a higher influence on the other ions, minerals, and organic matter. In this study, the concentration of Fe and Mn exceeded the standard allowed by the Ministry of Health for drinking water, therefore, an additional treatment for Fe and Mn removal should be applied if the water from RBF is going to be used as drinking water.

Keywords:
Groundwater, RBF, Iron, Manganese, River water

INTRODUCTION

One of the major issues in Malaysia is the degradation of river water quality. Therefore, finding an alternate drinking water supply is critical as water resources are becoming difficult to treat due to flooding, pollution, and illegal dumping. Water disruptions from several water treatment plants have been a result of river pollution and industrialization (Khalid, 2018). Furthermore, most of Malaysia's present water treatment system is not equipped with a treatment technology to effectively remove dissolved inorganic and organic substances such as heavy metals and pesticides. The authorities that are responsible for water management find it difficult to overcome the challenges of providing access to safe and clean water. For that reason, Malaysia needs to improve the water infrastructure and not rely 98% on river water as the major source to obtain high-quality drinking water.

River Bank Filtration (RBF) technology can be an alternate source to obtain high-quality drinking water on a larger scale. RBF system is a form of water treatment process that uses simple technology to operate by extracting water from rivers by pumping wells. This system significantly improves the quality of surface water through natural chemical, physical, and biological processes. It has been used in Europe for over a century and countries such as America, and Canada; even some South American countries have been using this technology (Ray, 2002). According to the experience

of these countries, the RBF system is capable of producing a high-quality water intake from the polluted river by going through natural filtration processes. However, this technology is considered relatively new in Malaysia and further understanding is required since the groundwater quality is dependent on the local soils and tends to carry high mineral content. Hence, there is a need to establish monitoring programs to oversee the water quality from the RBF.

The analysis made by previous research found that the concentrations of Fe and Mn are the most common contaminants found in the RBF system (Rashid & Abustan, 2020). This is a result of the geochemical activities within the soil layer which influence the concentration of Fe and Mn fluctuations in the groundwater. Fe and Mn are redox-sensitive minerals; therefore, a redox reaction plays an important role in the fluctuation of Fe and Mn level in the RBF system. The reduction and oxidation states along the flow path will increase and reduce the concentration of Fe and Mn in the water.

According to the Ministry of Health (MOH) Malaysia guidelines for drinking water, the permissible values for Fe and Mn in drinking water are 0.3 mg/l and 0.1 mg/l respectively. Long term consumption of metal-contaminated water poses a significant threat to the human body because of its bio-accumulative nature, persistence in the environment and toxicity (Alidadi, et al., 2019).
WHO guidelines, however, do not have any health-based guidelines for Fe levels. This was based on the view of Fe as an essential element for the survival and growth of plants, animals, and human life. This issue is of great concern, as Fe has been detected to be heavily abundant in the environment (Agoro, Adeniji, Adefisoye, & Okoh, 2020).

For Mn, the toxicology review by WHO, (2006) states that there is an association between the progressive increase of Mn-level concentrations and the progressive increase in the prevalence of the neurological effects as signs of chronic manganese poisoning. Based on these toxicity findings, several studies have argued the importance of reexamination of Mn (Frisbie et al., 2012).
Hence, this study analyzes the Fe and Mn concentrations in the RBF pumping well and the Kerian River in Malaysia, and compares the findings. Since Malaysia has plenty of rivers, the RBF system can easily be installed given the hydrogeological conditions and the water obtained from the RBF pumping well can produce high-quality water. Additionally, innovation in water treatment technologies helps to minimize the use of land, improve manufacturing capacity, is more cost-effective and decreases labor costs. The advancement and improvement of water treatment technologies are undeniably dependent on the declining condition of the water supply and the current demand for water over time because of population and business expansion (Huang et al., 2015). This study analyzes and compares the concentration of Fe and Mn at the RBF pumping well to the Kerian River. This study however does not use primary data. Therefore, there are limitations to this study where the study uses a specific sample size and parameters which means its findings cannot be generalized to other situations.

MATERIALS AND METHODS

Site Description

The Kerian River is located along the northern part of Malaysia that runs along the states of Penang, Kedah and Perak and flows into the straits of Malacca on the West Coast. The Kerian River has a length of 90 km and an area of 1,418 km^2, flat land with an elevation of 50 m above sea level and a relative relief of 1,525m. (National Water Resources Study Perak State Report, 2000). Thereby, knowledge in such relationships at a catchment scale across seasons is still lacking due to the large area and monitoring difficulties. Identifying the spatial and seasonal variability of land use impacts on water quality represents a significant challenge for understanding the land use impacts on water quality (Rodrigues, et al., 2018).

The weather in Malaysia is between 20 - 30 degrees on average, throughout the year; however, mountainous terrains experience colder temperatures. Malaysia experiences two monsoons, depending on the area, the south-west (Malacca Straits) experiences the monsoon from May to September and the north-east experiences it from November to March. Depending on the location of the study, the dataset varies depending on weather and seasonality in that period.

Data Analysis

A total of 20 data sets obtained from the RBF pumping well and Kerian River water (Ibrahim, 2018) were used for the descriptive statistic and correlation analysis in this study. The data was collected over a duration of five months from April to August 2015. The water samples collected had been properly preserved and tested according to the APHA 2005, American Public Health Association Standard Method for the Examination of Water and Wastewater. This study uses MS Excel to determine the descriptive analysis which includes mean, standard deviation, skewness, and kurtosis. Another analysis that was also used in this study is the Pearson correlation of regression analysis.

RESULTS AND DISCUSSION

Table 1 presents the results of descriptive analysis for RBF pumping well. The results show that the standard deviation (SD) for temperature, pH, and Mn is less than 1 (<1) indicating that the values are close to each other. Whereas Turbidity, Color, TDS, TSS and Fe are larger than 1 and less than 10 (1<x= parameter SD<10) indicating that the data fluctuates. The remaining parameter, Conductivity, which demonstrated SD greater than 10 (>10), means that the data points are spread out and inconsistent. The skewness value between -0.5 to 0.5 indicates that the distribution is approximately symmetrical for the parameters such as conductivity, Fe and Mn.

Table 1: Descriptive Analysis of the RBF Pumping Well

SN	Parameters	Unit	Counts	Mean	SD	Min.	Max.	Sum	Skewness	Kurtosis
1	Temperature	C	5	28.56	0.33	28.32	29.1	142.8	1.61	2.53
2	pH	-	5	6.5	0.196	6.2	6.74	32.5	-0.77	2.1
3	Conductivity	uS/cm	5	91.05	11.15	76.41	101.6	455.2	-0.47	-2.15
4	Turbidity	NTU	5	1.59	1.67	0.18	4.205	7.93	1.13	0.71
5	Color	PtCo	5	3.2	3.89	1	10	16	1.99	3.95
6	TDS	ppm	5	58.72	8.1	47.15	293.6	293.6	-0.74	-1.16
7	TSS	ppm	5	4.7	4.82	1	23.5	23.5	1.85	3.6
8	Fe	ppm	5	4.82	3.88	0.062	8.8	24.11	0.043	-2.27
9	Mn	ppm	5	0.19	0.155	0.0036	0.927	0.927	0.29	-1.21

The skewness value between −1 to – 0.5 and 0.5 to 1 exhibits by pH and TDS indicates that their distribution is moderately skewed. Lastly, the skewness value of parameters greater than (> -1,1) such as temperature, turbidity, color and TSS is positively skewed.

In term of Kurtois, color and TSS of RBF pumping well water has a value greater than 3 (> 3) which show that the distribution is leptokurtic. On the other hand, parameters such as temperature, pH, conductivity, turbidity, TDS, Fe and Mn have the value of kurtosis of lesser than 3 (< 3), indicating that the distribution is platykurtic.

The descriptive analysis of Kerian River water is shown in Table 2. The standard deviation (SD) for temperature, pH, Fe and Mn is less than 1 (<1), which is close to zero indicating that the values are close to each other, whereas conductivity, color, TDS are greater than 1 and less than 10 (1<x= parameter SD<10) indicating that the data fluctuates. The remaining parameters such as Turbidity and TSS exhibit SD of greater than 10 (>10), which is high and shows that the data are spread out. The skewness value between -0.5 to 0.5 indicates that the distribution is approximately symmetrical, which are the parameters such as temperature, turbidity, and color. The skewness value between (−1 to – 0.5, 0.5 to 1) indicates that the distribution is moderately skewed for parameters such as pH, conductivity, TDS and TSS. Lastly, the skewness value of parameters greater than (> -1,1) such as Fe and Mn are positively skewed. Kurtosis value of greater than 3 (> 3) indicates that the distribution is leptokurtic for parameters such as Mn. Kurtosis value of less than 3 (< 3) indicates that the distribution is platykurtic for parameters such as temperature, pH, conductivity, turbidity, color, TDS, TSS and Fe.

Table 2: Descriptive Analysis of the Kerian River

SN	Parameters	Month / Unit	Counts	Mean	SD	Min.	Max.	Sum	Skewness	Kurtosis
1	Temperature	C	5	28.0	0.78	27.1	28.85	140.01	-0.043	-2.63
2	pH	-	5	5.57	0.46	4.89	6.13	27.83	-0.52	0.81
3	Conductivity	uS/cm	5	37	5.24	30.35	44.9	185.1	0.55	1.73
4	Turbidity	NTU	5	80.17	17.8	59.3	103.6	400.85	0.27	-1.47
5	Color	PtCo	5	27.3	4.84	21	33	136.5	-0.13	-1.47
6	TDS	ppm	5	24.1	3.46	19.7	29.3	120.5	0.56	1.72
7	TSS	ppm	5	106.4	12.22	88	119	532	-0.77	0.32
8	Fe	ppm	5	0.171	0.25	0	0.567	0.852	1.38	0.76
9	Mn	ppm	5	0.00056	0.001	0	0.0028	0.0028	2.2361	5

From the results in Tables 1 and 2, it is clearly seen that Fe and Mn are both positively skewed from both locations. However, the same could not be said for kurtosis as the value at the pumping well shows a negative kurtosis while the Kerian river shows positive kurtosis. In contrast, both Fe and Mn possess a linear relationship with similar representation.

Pearson Correlation for Kerian River and RBF pumping well

The results for Pearson correlation analysis for the Kerian River and RBF pumping well are presented in Table 3. In this analysis, the relationship between Fe and Mn with other water quality parameters such as temperature, pH, EC, turbidity, colour, TDS and TSS were determined.

Table 3: Correlation Analysis for Kerian River and RBF pumping well

Kerian River	*Temperature*	*pH*	*EC*	*Turbidity*	*Color*	*TDS*	*TSS*	*Fe*	*Mn*
Fe	*0.293*	*0.238*	*0.481*	*0.363*	*-0.660*	*0.484*	*0.410*	*1.000*	
Mn	*0.608*	*0.301*	*0.094*	*0.372*	*-0.323*	*0.097*	*0.439*	*0.889*	*1.000*
RBF well	*Temperature*	*pH*	*EC*	*Turbidity*	*Color*	*TDS*	*TSS*	*Fe*	*Mn*
Fe	*-0.310*	*-0.175*	*0.587*	*0.300*	*0.723*	*0.538*	*0.519*	*1.000*	
Mn	*-0.183*	*-0.423*	*0.532*	*0.311*	*0.850*	*0.478*	*0.310*	*0.963*	*1.000*

According to the linear regression analysis for the Kerian River water in Table 3, Fe and Mn showed the strongest correlation with r = 0.889. The strong correlation demonstrated the highest influence of the parameter on each other. In this case, when the concentration of Fe is high, the concentration of Mn will be high. It can be said that 89% of the variation in Mn was influenced by Fe or vice versa. The relationship between Fe and colour is also significant with r = -0.723 indicating 72% of variation in colour in Kerian River water was influenced by the presence of Fe. However, the negative sign in the value insinuated a contrasting relationship where an increase of Fe in water will reduce the amount of colour. This finding is interesting because the result is opposite to the common understanding where iron is known to contribute to brownish colour in water. At the same time, Fe is also moderately correlated with EC (r = 0.481), TDS (r = 0.484), and TSS (r = 0.410). However, Mn in the Kerian River water is only highly correlated to Fe (r = 0.889) and moderately correlated to temperature (r = 0.608) and TSS (r = 0.439). The results also show that Mn presence in the water is not significantly influenced by pH, EC, colour, turbidity and TDS.

Similar to Kerian River water, Fe in RBF pumping well shows a high correlation to Mn (r = 0.963) and colour (r = 0.723). Contrarily, the relationship between Fe and colour in RBF pumping well is positively correlated which means an increase of Fe will also increase the colour. Besides that, the Fe is also moderately correlated with pH (-0.423), EC (r = 0.587), TDS (r = 0.538), and TSS (r = 0.519) but with a slightly higher correlation than the Kerian River water sample. On the other hand, temperature (-0.310), pH (r = -0.175), and turbidity (r = 0.300) show an insignificant relationship with Fe. Mn relationship with Fe (r = 0.963) and colour (r = 0.850) is highly correlated followed by pH (r = 0.81), EC (r = 0.532) and TDS (r = 0.478) with moderate correlation.

It can be seen from the regression correlation, Fe is not the factor that influenced colour in the Kerian River water but had a large influence in well water. This finding shows that the concentration of iron is mainly contributed by the presence of mineral in the existing soil which is complimented by the concentration of Fe presented in Table 1 and Table 2 respectively. In this case, Fe is typically carried into the pumping well during the natural filtration process from the river to the pumping well. Other than that, it can be concluded that in both RBF pumping well and Kerian River, Fe and Mn concentration has a strong positive correlation (i.e., they influence each other's concentrations). Meanwhile, the medium correlation between Fe and Mn with TDS and EC in RBF

pumping well water also indicated high concentrations of minerals and ions present in the water (Nasir et al., 2019).

CONCLUSION

Statistical analysis has shown to be an important tool that is used to analyze the data. Using this tool helps to obtain a significant relationship between the Fe and Mn concentration pairing with different physical and chemical parameters of the water sample. This method of analysis has proven to be a significant approach to understanding the relationship between the variable and visualize the quality of the Kerian River and the pumping well water samples. River water quality is easily influenced by external factors such as surrounding activities and land use. On the contrary, well water is mainly influenced by the soil layer and mineral present in the soil. In this study, the water quality of Kerian River water quality improved in term of colour, turbidity and TSS after RBF but the higher concentration of Fe and Mn detected makes it less suitable to be used as drinking water without further treatment to reduce the concentration of Fe and Mn in the water.

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International Journal of Infrastructure Research and Management
Vol. 11 (1), June 2023, pp. 77 - 87

ANALYSIS OF COUNTERMEASURES FOR RISK MANAGEMENT OF CONSTRUCTION ENGINEERING

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ABSTRACT
With the continuous progress of the social economy, construction building projects have been greatly developed. Construction building projects have been greatly improved in the number, size and investment and other aspects. Coupled with the growing quality of living, the construction building projects are also required to put forward more requirements in the quest for continuous improvement. The benefits of conducting risk analyses in the planning of construction projects are widely acknowledged. However, the actual implementation of procedures notably differs significantly across industry segments. At the same time, in the process of the construction project, it is inevitable to encounter some uncertain factors, which make construction projects face many risks. If no active measures are taken to deal with these risks, then it is likely to give rise to serious quality problems in construction projects. This would bring huge economic losses, and pose a serious threat to people's life and property security. Therefore, it is very important to strengthen the risk management aspect of construction engineering construction projects. This article analyzes the different forms of process improvement used in the development of construction projects in Chengdu City, China. Through interviews, one project was selected as a case study. The research aimed to analyze the meaning, allocation principles and strategies of engineering risks. It adopted a combination of theoretical analysis and practical research, and combined qualitative and quantitative research methods to study risk awareness of projects, attempting to look at risk prevention plans in a more scientific and reasonable manner. This would lead to the realization of reasonable allocation of risks to provide a maximizing the possibility of the success of a project

Keywords:
Construction engineering. Construction project. Risk management.

INTRODUCTION

These years, the construction industry has developed rapidly in China which has an active market. The stakeholders of the construction industry have to elevate their comprehensive capacity to respond to the intense competition and seek more benefits. For each construction project, effective management is very important in the successful realization of the project. Construction projects have some common points, such as huge goods and materials consumption, long construction period, wide coverage, single process, a number of participants, high demands of coordination and so on. It is those characteristics that lead to the existence of many risks starting from the feasibility study stage, reconnaissance and design stage, construction stage, and the completion certification of a project. If those risks are not managed well, they may cause serious damage to the stakeholders and even result in a project not being completed. This is an undesirable circumstance that no one wants to see. So, this study has its grounds in the need to pay attention to risk management works and to improve the risk management theory. There is a strong practical significance of this study.

Risk management is an essential part of construction projects which aims at identifying the potential risks associated with a project and responding to those risks to reduce them to an acceptable extent. Risk management is indeed a dynamic tool that must be continuously applied throughout the project life cycle (Lu & Yan, 2013). Risk management is based on intuition and past experience for a high level of judgment. There are three main processes in risk management which are risk

identification, risk analysis, and risk response. It should be borne in mind that the main principle of risk management is not about eliminating all the risks but controlling them properly. The construction project is overwhelmed by many predictable and unpredictable risks due to different sources of uncertainty, which include the performance of construction parties, resource availability, environmental conditions (Serpella et al., 2014), the involvement of other parties, and contractual relations. The main objectives of risk management in a construction project include completing the project within the specified cost and time and within the required quality, safety, and environmental limits.

In terms of involvement in research and application of theories of engineering project risk management, China started relatively late, and in many respects, it is quite backward compared to developed countries（Liang, 2018). The market is chaotic. It is precisely because of these shortcomings that research, application, and development should be done. In construction project management, risk management, like other forms of management including safety management, contract management, information management, etc., is a very important part of management (Qiu, 2018).

The environment of construction projects is very complicated and is easily affected by natural and social factors. In view of these influencing factors, under normal circumstances, construction personnel often lack knowledge of strong preventive measures and means, and methods to achieve effective control, which in turn leads to project goals that do not meet expected requirements and ultimately leads to "risks" (Zhou, 2019）. Therefore, in order to protect the economic benefits of construction enterprises, it is necessary to fully understand the nature of risks, effectively identify the risks of engineering projects, analyze and study the root causes of risks, and make correct judgments on the impact of risks, and based on this, effective measures can be taken to achieve effective risk control (Xiao, 2019)l. Once the countermeasures and plans are improperly adopted, it will increase the construction cost of the construction enterprise and adversely affect the economic benefits of the enterprise (Zhou, 2020).

This study investigated the site at the flower park construction project in Anren Town, Chengdu, China. Project-related experts were selected, and a direct communication relationship with these experts was established. All expert opinions were collected by way of correspondence. Through a questionnaire, the identification, analysis and evaluation of risks, risk management workers can recognize the nature and characteristics of the risks they are facing, and have evidence to rely on when formulating risk control strategies. Through this, the plans formulated are more reasonable and effective. It reduces the possibility of encountering risks, increases the chances of making profits, improves the ability to deal with emergencies, improves management quality, and provides important reassurance for the smooth completion of the project and the realization of various goals.

LITERATURE REVIEW

Various industries will have project risk management, but different industries have different characteristics. As far as the construction industry is concerned, its risks are greater, and management is more complex and more difficult. Risk management of construction projects refers to the identification, analysis, and evaluation of potential risks by the construction unit, and effective disposal measures (Raisbeck, 2018) to deal with the impact of risks, so as to make the construction safe at the lowest cost. A scientific management method to obtain the greatest degree of assurance, risk management of construction projects is to effectively control the construction period, quality, cost, and safety of construction projects.

There are many problems in the risk management of construction projects. In the actual construction process, it is inevitable to encounter natural risks, which are often unavoidable, mainly involving natural disasters such as severe weather conditions and mudslides. Although the natural

environment often causes great risks, it can be prevented with scientific construction plans. In terms of economic risks, in the current economic environment which is facing problems, the operation of construction projects often comes with great risks, such as the increase in labor costs and the adjustment of construction material costs. In the process of construction engineering, the safety of construction sites is one of the main issues. Because construction projects often require a large number of construction personnel, engaged in high-altitude operations, this results in greater construction risks. This in turn requires prior identification and prevention of possible risks.

For all staff engaged in risk management of construction projects, （Lu et al., 2002）clarifying the risks is conducive to the macro-control of the direction and focus of the work, and it can also make the risk management work organized and conducive to improving management efficiency. In short （Wei, 2000）the content of project risk management can be summarized into the following four characteristics: Risk identification, Risk analysis, Risk response, and Risk treatment.

In construction projects, it is not only necessary to identify risks, but also to conduct risk analysis based on the results of risk identification to assess the possibility of various risks and the magnitude of the impact on the project. There are many methods for risk assessment, and the comprehensive evaluation method is a commonly used evaluation method, including the lowest evaluation price and the comprehensive scoring method (Zhou, 2019). This mainly requires qualitative analysis that is supported by quantitative analysis. Sufficient relevant information needs to be obtained to make a reasonable overall evaluation of project risks. The second is the analytic hierarchy process, which needs to determine the evaluation object, as well as the criteria, details, and various indicators of this evaluation activity, and establish a hierarchical risk evaluation model based on these data. After establishing the model, the judgment matrix can be developed. In practical applications, it is necessary to arrange the order according to the relative weights of various risks.

RESEARCH METHODOLOGY

The methodologies used in this study include quantitative and qualitative approaches to analyze the data obtained. The data was analyzed using SPSS software. The qualitative and quantitative data were combined and analysed using the Fuzzy analysis method. First, the relevant expert engineers involved in the project construction were identified, and then direct correspondence with these experts was established, with a total of 17 interviewees, including senior engineers, designers, construction engineers and cost engineers. Expert opinions were collected by way of correspondence. These experts include designers, engineers and project managers. This research obtained data from a case study conducted in Chengdu, China. The researcher had a face to face contact with each expert and explained the purpose of the questionnaire, and then briefly explained the content of each part of the questionnaire. The experts then completed the questionnaire and were interviewed. Finally, these opinions were collected and integrated. Based on this, feedback was given to experts, and opinions were then collected again.

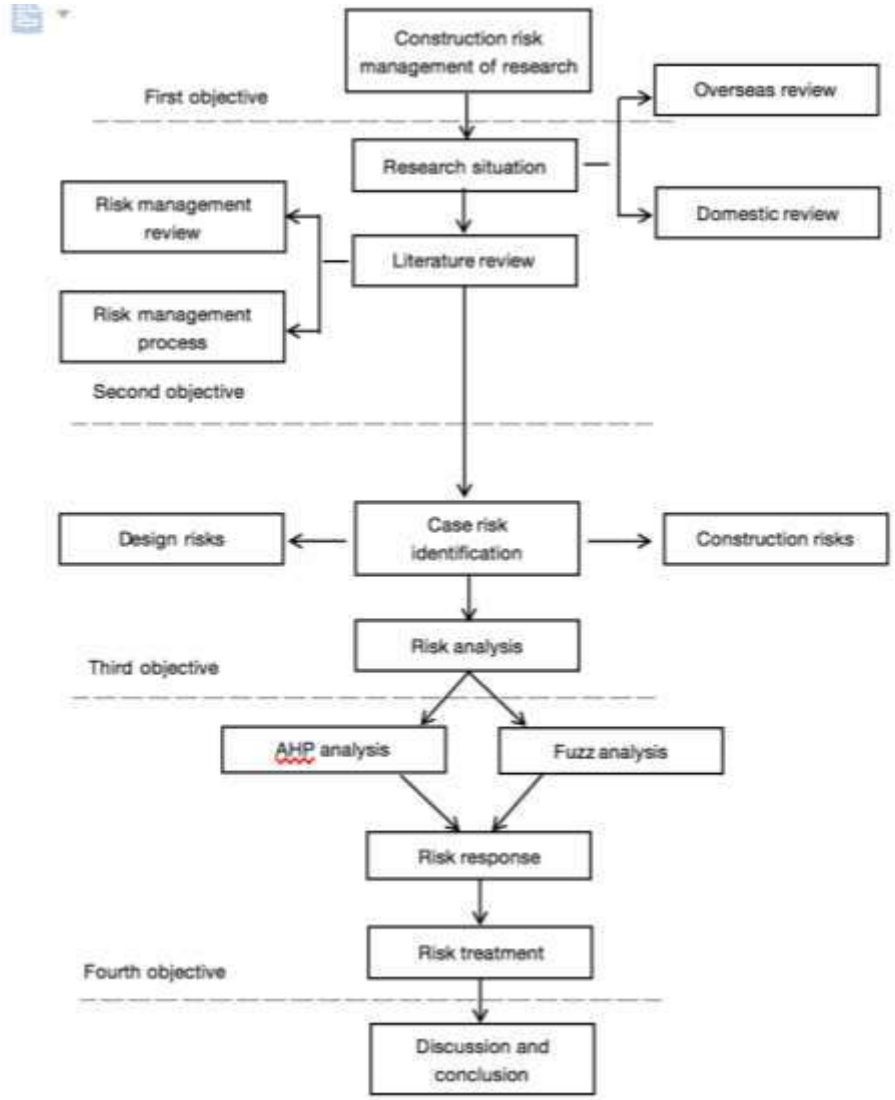

Figure 1: Research Framework

RESULTS AND DISCUSSION

The Flower Park Project is located in Anren Town, Chengdu City, Sichuan Province. The park covers an area of 39 acres, including 32 acres of green space and 2.8 acres of water, with a green space rate of about 83%.

According to the introduction of the construction project risk identification index system, combined with the actual situation of the Flower Park Project in Anren Town, the project risk fuzzy analysis method was identified. The primary risk factors are mainly design stage risks, construction stage risks, bidding stage risks and other risks. The fuzzy comprehensive evaluation method is a comprehensive evaluation method based on fuzzy mathematics. The comprehensive evaluation method transforms qualitative evaluation into quantitative evaluation according to the membership degree theory of fuzzy mathematics, that is, using fuzzy mathematics to make a general evaluation of things or objects restricted by many factors. It has the characteristics of clear results and strong systematicness, which can better solve vague and difficult-to-quantify problems, and is suitable for solving various non-deterministic problems.

Table 1: Statistics of the measurement results of each item of the scale

Items	strongly disagree (%)	disagree（%）	Neutral (%)	Agree(%)	Very much agree（%）	mean	standard deviation
I don't think a feasibility analysis has been done on the construction project	24.27	28.87	31.38	12.13	3.35	2.414	1.085
I think the lack of project risk management plan for construction projects	24.27	30.13	33.47	9.62	2.51	2.360	1.031
I think construction projects are planned hastily and not well enough	21.34	36.40	28.03	9.62	4.60	2.397	1.068
I think the information provided by the owner of the construction project is incomplete and the requirements are not clear	25.10	36.82	24.27	9.62	4.18	2.310	1.079
I think the planning conditions for construction projects have changed	23.43	30.13	30.13	12.97	3.35	2.427	1.086
I think the unit in charge of the construction project has made an improper choice of the design unit	37.24	19.67	22.18	19.25	1.67	2.285	1.200
I think that the selection of the design scheme by the unit responsible for the construction project is at risk	20.92	32.64	29.29	12.55	4.60	2.473	1.095
I think the construction project is not designed according to the normal design stage	26.78	33.47	24.27	12.55	2.93	2.314	1.087

I think the scope of the design content of the construction project is not clear	19.67	31.38	30.96	12.13	5.86	2.531	1.114
I think construction drawings for construction projects are not deep enough	22.59	28.87	30.96	13.81	3.77	2.473	1.099
I think the review and supervision system of the design company corresponding to the construction project is not perfect	19.25	33.89	30.96	12.97	2.93	2.464	1.036
I don't think the skills and methods of the designers involved in the construction project are adequate	22.18	32.64	29.71	12.13	3.35	2.418	1.065
I think the construction process of the construction project is flawed	24.69	35.98	23.85	12.13	3.35	2.335	1.079
I think there is a problem with the quality of construction equipment for construction projects	28.03	30.54	29.29	8.37	3.77	2.293	1.080
I think construction projects have engineering quality risks	23.85	36.40	28.03	8.79	2.93	2.305	1.022
I think there is a risk of construction delay in construction projects	26.36	34.73	27.62	7.11	4.18	2.280	1.062
I think the general design document of the construction project is not very guiding	27.20	35.56	26.78	7.53	2.93	2.234	1.027
I think that the construction operators of construction projects have insufficient experience and ability	30.96	29.29	25.94	10.46	3.35	2.259	1.107
I think there is a lack of material preparation for construction projects	30.54	29.29	28.03	10.46	1.67	2.234	1.051
I think the construction responsibility of the construction project is not clear	45.19	21.76	14.23	18.41	0.42	2.071	1.170
I think there is a situation in which construction projects are designed and constructed at the same time	27.62	32.22	25.10	10.04	5.02	2.326	1.131
I think the construction side of the construction project is not skilled enough	26.36	37.24	24.69	8.37	3.35	2.251	1.043

I think the design bidding process for construction projects is illegal and non-standard	19.25	27.62	33.89	16.32	2.93	2.561	1.067
I think there is a risk of ambiguous assignment of responsibilities between the two parties in the design contract terms in construction projects	21.34	29.71	33.05	13.39	2.51	2.460	1.048
I think the design bidding documents for construction projects are irregular and inaccurate	33.05	15.90	22.59	26.36	2.09	2.485	1.253
I think the construction bidding process of construction projects is illegal and irregular	20.08	32.64	30.13	14.23	2.93	2.473	1.056
I think the construction bidding documents for construction projects are irregular and inaccurate	21.34	28.45	28.03	17.57	4.60	2.556	1.143
I think there is a risk of ambiguous assignment of responsibilities between the two parties in the construction contract terms of a construction project	20.08	34.31	28.45	13.39	3.77	2.464	1.072
I think natural disasters often occur in the location of construction projects	18.41	36.82	30.54	10.04	4.18	2.448	1.035
I think construction projects are vulnerable to government policy adjustments	35.15	19.25	19.25	25.52	0.84	2.377	1.227
I think the geographical environment risk is high in the location where the construction project is located	20.92	30.54	33.05	10.88	4.60	2.477	1.080
I think the economic situation where the construction project is located has deteriorated	20.08	35.98	26.78	14.64	2.51	2.435	1.047

Through frequency analysis and description, the percentage ratio and corresponding mean value of each item option in the above table were counted. The results are shown in the above table. According to the weight of the AHP method, the fuzzy comprehensive evaluation was further carried out in combination.

1) Design Risk Judgment Results

$$\mathbf{a1} = \begin{pmatrix} \mathbf{0.2427\ 0.2887\ 0.3138\ 0.1213\ 0.0335} \\ \mathbf{0.2427\ 0.3013\ 0.3347\ 0.0962\ 0.0251} \\ \mathbf{0.2134\ 0.3640\ 0.2803\ 0.0962\ 0.0460} \\ \mathbf{0.2510\ 0.3682\ 0.2427\ 0.0962\ 0.0418} \\ \mathbf{0.2343\ 0.3013\ 0.3013\ 0.1297\ 0.0335} \\ \mathbf{0.3724\ 0.1967\ 0.2218\ 0.1925\ 0.0167} \\ \mathbf{0.2092\ 0.3264\ 0.2929\ 0.1255\ 0.0460} \\ \mathbf{0.2678\ 0.3347\ 0.2427\ 0.1255\ 0.0293} \\ \mathbf{0.1967\ 0.3138\ 0.3096\ 0.1213\ 0.0586} \\ \mathbf{0.2259\ 0.2887\ 0.3096\ 0.1381\ 0.0377} \\ \mathbf{0.1925\ 0.3389\ 0.3096\ 0.1297\ 0.0293} \\ \mathbf{0.2218\ 0.3264\ 0.2971\ 0.1213\ 0.0335} \end{pmatrix}$$

$$\mathbf{Aa1} = \begin{pmatrix} \mathbf{0.1187\ 0.0788\ 0.1072\ 0.0755\ 0.146\ 0.0396\ 0.0392\ 0.0753\ 0.1057\ 0.1051\ 0.0373} \\ \mathbf{0.0716} \end{pmatrix}$$

$$\mathbf{Ba1} = \mathbf{Aa1} \cdot \mathbf{Ra1} = (\mathbf{0.2347}\ \ \mathbf{0.3141}\ \ \mathbf{0.2926}\ \ \mathbf{0.1213}\ \ \mathbf{0.0373})$$

The results show that in terms of design risk, the surveyed groups chose "strongly disagree" with 23.47%, "disagree" with 31.41%, "neutral" with 29.26%, and "agree" with 12.13%. The "high" rate is 3.73%, and the conclusion is "disagree" according to the principle of maximum membership, indicating that the design risk of the building project is low.

2) Construction Risk Judgment Results

$$\mathbf{Ra2} =$$

$$\mathbf{Ra2} = \begin{pmatrix} \mathbf{0.2469\ 0.3598\ 0.2385\ 0.1213\ 0.0335} \\ \mathbf{0.2803\ 0.3054\ 0.2929\ 0.0837\ 0.0377} \\ \mathbf{0.2385\ 0.3640\ 0.2803\ 0.0879\ 0.0293} \\ \mathbf{0.2636\ 0.3473\ 0.2762\ 0.0711\ 0.0418} \\ \mathbf{0.2720\ 0.3556\ 0.2678\ 0.0753\ 0.0293} \\ \mathbf{0.3096\ 0.2929\ 0.2594\ 0.1046\ 0.0335} \\ \mathbf{0.3054\ 0.2929\ 0.2803\ 0.1046\ 0.0167} \\ \mathbf{0.4519\ 0.2176\ 0.1423\ 0.1841\ 0.0042} \\ \mathbf{0.2762\ 0.3222\ 0.2510\ 0.1004\ 0.0502} \\ \mathbf{0.2636\ 0.3724\ 0.2469\ 0.0837\ 0.0335} \end{pmatrix}$$

$$\mathbf{Aa2} = (\mathbf{0.1229\ 0.0988\ 0.1431\ 0.0975\ 0.0510\ 0.0944\ 0.0722\ 0.0696\ 0.1328\ 0.1178}\ )$$

$$\mathbf{Ba2} = \mathbf{Aa2} \cdot \mathbf{Ra2} = (\mathbf{0.2822}\ \ \mathbf{0.3291}\ \ \mathbf{0.2560}\ \ \mathbf{0.1000}\ \ \mathbf{0.0329})$$

The results show that in terms of construction risk, the surveyed groups chose "strongly disagree" with 28.22%, "disagree" with 32.91%, "neutral" with 25.60%, and "agree" with 10.00%. The proportion of "high" is 3.29%, and according to the principle of maximum membership, the conclusion is "disagree", indicating that the construction risk of the building project is low.

3) Bidding Risk Judgment Results

$$\mathbf{Ra3} = \begin{pmatrix} \mathbf{0.1925\ 0.2762\ 0.3389\ 0.1632\ 0.0293} \\ \mathbf{0.2134\ 0.2971\ 0.3305\ 0.1339\ 0.0251} \\ \mathbf{0.3305\ 0.1590\ 0.2259\ 0.2636\ 0.0209} \\ \mathbf{0.2008\ 0.3264\ 0.3013\ 0.1423\ 0.0293} \\ \mathbf{0.2134\ 0.2845\ 0.2803\ 0.1757\ 0.0460} \\ \mathbf{0.2008\ 0.3431\ 0.2845\ 0.1339\ 0.0377} \end{pmatrix}$$

$$\mathbf{Aa3} = (\mathbf{0.2567\ 0.1715\ 0.0868\ 0.243\ 0.0851\ 0.1568}\ )$$

$$\mathbf{Ba3} = \mathbf{Aa3} \cdot \mathbf{Ra3} = (\mathbf{0.2131\ \ 0.2930\ \ 0.3050\ \ 0.1583\ \ 0.0306})$$

The results show that in terms of bidding risk, the surveyed groups chose "strongly disagree" with 21.31%, "disagree" with 29.30%, "neutral" with 30.50%, and "agree" with 15.83%, the proportion of "high" is 3.06%, and according to the principle of maximum membership, the conclusion is "neutral", indicating that the bidding risk of the construction project is low.

4) Other Risk Judgment Results

$$\mathbf{Ra4} = \begin{pmatrix} \mathbf{0.1841\ 0.3682\ 0.3054\ 0.1004\ 0.0418} \\ \mathbf{0.3515\ 0.1925\ 0.1925\ 0.2552\ 0.0084} \\ \mathbf{0.2092\ 0.3054\ 0.3305\ 0.1088\ 0.0460} \\ \mathbf{0.2008\ 0.3598\ 0.2678\ 0.1464\ 0.0251} \end{pmatrix}$$

$$\mathbf{Aa4} = (\ \mathbf{0.2486\ 0.2618\ 0.2479\ 0.2417})$$

$$\mathbf{Ba4} = \mathbf{Aa4} \cdot \mathbf{Ra4} = (\mathbf{0.2382\ \ 0.3046\ \ 0.2730\ \ 0.1541\ \ 0.0301})$$

The results showed that, in terms of other risks, the surveyed group chose "strongly disagree" with 23.82%, "disagree" with 30.46%, "neutral" with 27.30%, and "agree" with 15.41%. “High" was 3.01%, and according to the principle of maximum membership, the conclusion was "disagree", indicating that other risks of the construction project are low.

5) Second-level Fuzzy Judgment Results

According to the single-factor first-level evaluation made above, combined with the first-level index weight of the AHP, the second-level fuzzy evaluation was carried out.

$$\mathbf{Ra} = \begin{pmatrix} \mathbf{0.2347} & \mathbf{0.3141} & \mathbf{0.2926} & \mathbf{0.1213} & \mathbf{0.0373} \\ \mathbf{0.2822} & \mathbf{0.3291} & \mathbf{0.2560} & \mathbf{0.1000} & \mathbf{0.0329} \\ \mathbf{0.2131} & \mathbf{0.2930} & \mathbf{0.3050} & \mathbf{0.1583} & \mathbf{0.0306} \\ \mathbf{0.2382} & \mathbf{0.3046} & \mathbf{0.2730} & \mathbf{0.1541} & \mathbf{0.0301} \end{pmatrix}$$

$$\mathbf{Aa} = (\mathbf{0.2703\ 0.4124\ 0.2541\ 0.0632})$$

$$\mathbf{Ba} = \mathbf{Aa} \cdot \mathbf{Ra} = (\mathbf{0.2490\ \ 0.3143\ \ 0.2794\ \ 0.1240\ \ 0.0333}\ )$$

In the overall measurement results of the risk in the design and construction stage of construction projects, the surveyed group chose "strongly disagree" with 24.90%, "disagree" with 31.43%, "neutral" with 27.94%, and "agree" The proportion of "high" is 12.40, and the proportion of "high" is

3.33%. According to the principle of maximum membership, the conclusion is "disagree", indicating that the overall risk of the construction project in the design and construction stage is low.

Overall, this study mainly introduces the use of different analysis methods to analyze and explore the collected data. The research mainly adopts the questionnaire survey to obtain the survey data. Then SPSS analysis software was used to analyze the data to find out the risk indicators of the project. The analysis indicated that the overall risk in the design and construction phases of the construction project was low and this is aligned to the expected results.

CONCLUSION

Through the specific situation of the construction of the Flower Park Project, the actual problems were put forward. After the preliminary analysis of the project risk factors, the risk of the project was evaluated, and the fuzzy method was used to obtain the main risk factors for the project. For the main risk factors identified by scientific methods, a set of corresponding risk suitability response strategies were established to effectively prevent unknown risks and minimize the uncertainty of risks. So far, based on practical examples, a more comprehensive understanding of project risk management was derived from theory, minimizing the risks encountered by engineering projects, which played a guiding role in the risk management of future engineering projects.

At the same time, based on the literature read, the workflow of construction engineering and the risk management process was sorted and analyzed. By studying risk management at home and abroad, understanding risk management methods, and combining construction engineering, a set of risk identification methods that conform to the characteristics of construction engineering design were identified where the reference value was summarized, and a reasonable control method to reduce the impact of risks was given. This enriches the construction engineering risk management system and provides effective theoretical guidance for the healthy development of the industry.

This study discusses the relevant factors of construction engineering risk and uses a combination of theoretical analysis and event research. The combination of qualitative and quantitative approaches, and systematic analysis leads to a more comprehensive analysis of the design risk, construction risk, and bidding risk of construction engineering. The law of occurrence and development helped to discuss the theories and methods of risk management and draw research results and conclusions. It is believed that the current construction engineering risk awareness is very weak, and the awareness of risk management should be improved to make the future and development direction of risk management clear. The methods of risk identification and control will be more abundant and perfect, and the risk management of construction projects will be more efficient.

ACKNOWLEDGEMENT

I sincerely thank my supervisor Dr Aliaa and Dr Nizam for their consistent support of my project and encouragement of patience and professional guidance. At the same time, I want to thank the manager Mr Zhu Xin Xin and Qin Shen Quan who were my intern at CRCC Malaysia Berhad. They gave me a lot of help and encouragement on my thesis. I would also like to thank my friends in IUKL who have accompanied me along the way during my studies and gave me their support and encouragement.

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International Journal of Infrastructure Research and Management
Vol. 11 (1), June 2023, pp. 88 - 95

THE CHEMICAL PROPERTIES OF GRANITE AND BERANANG LATERITE AGGREGATE BY USING SEM-EDX

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ABSTRACT
The chemical properties of coarse aggregate give significant impact on the concrete performance as it is the highest constituent in the concrete mix. The paper presents the chemical properties of granite and Beranang laterite aggregates upon the morphology and chemical composition of them in concrete mix. A separate batch was prepared consisting 200 g of granite and Beranang Laterite each. These batches were tested upon morphology and chemical compositions by using SEM-EDX set up. Based on the results, it was shown that the major composition of granite is silicon, carbon and oxygen whereas for Beranang Laterite shown silicon, carbon, silicon and ferum as its major compositions. There is a slight difference between two of them due to the different process in producing the aggregate. For granite, it is produced by cooled magma whereas the Beranang Laterite is produced by a weathering process which results in the chemical composition difference. In conclusion, both aggregates shared similar morphology and chemical compositions and proved that they are able to contribute to the concrete strength.

Keywords:
Chemical Properties of Aggregate, Laterite Aggregate, Laterite Concrete, Alternative Concrete Mix, Green Concrete

INTRODUCTION

Generally, approximately 60–75% of the volume concrete comprises by the aggregates. Indirectly, the properties and types of aggregate would affect the overall performance and economical value of the concrete (Rawaz Kurda, 2018). The rapid development has pushed the aggregate demand curve out to the right and become a massive pressure on supply of constituent materials of concrete to satisfy the industry demands (Natt Makul, 2020). Utilization natural resources such as river sand and granite as aggregates in concrete have led to deterioration of ecosystems. Therefore, the current research focus is on alternative materials for fine and coarse aggregates to balance the curve. One of the high potentials to be used as alternative material is laterite aggregate**.**

In early 1800s located in South India, laterite was used as aggregate in construction field (Basavana Gowda *et. al.*, 2018). In the beginning, the word laterite has been used by Buchanan in early 1807 to describe a vesicular and ferruginous to the unstratified and porous materials with yellow ochre (Zubair Saing et. al., 2018). It was found that a large deposit of laterite in tropical region around the world such as Africa, Thailand, Indonesia, India and other tropical regions globally. In addition, the laterite aggregate also can be found at Peninsular of Malaysia especially in Kelantan, Pahang, Johor, Selangor, Kedah and Negeri Sembilan. However, even though laterite aggregate was easily and abundantly available in Malaysia, it is not fully utilized in construction due to several unknown factors (Mohammad Razip Selamat et. al., 2017). In order to full utilize the laterite aaggregate, the properties of it need to be investigated especially on the chemical properties to ensure that Malaysian laterite aggregate has the suitable chemical properties to be used in concrete mixes. The main focus of this study is to analyse the chemical properties of granite and laterite aggregate and their impact on the strength and performance on concrete mix comprising these two materials as coarse aggregate.

METHODOLOGY

Materials

In the research, the laterite aggregate is collected from the ground surface which was located at Beranang, Selangor as exhibited in Figure 1. The granite aggregate was supplied by the Kajang Quarry, Selangor. Both types of aggregates were used with the particle size within the range of 5 mm to 10 mm. All test carried out upon the aggregate was based on the standard and guidelines from the BS EN 12620 (2008). The stockpiles of laterite aggregate collected need to be treated to eliminate the deleterious materials and to make sure the moisture content in the aggregate is in the saturated surface dry as shown in Figure 2. This is in order to make sure the chemical test carried out will produce accurate results.

Figure 1: The laterite aggregate is taken from ground surface at Beranang

Figure 2: The granite and laterite are treated for properties preservation

EXPERIMENTAL PROGRAMME

The experiments have been set up to determine the morphology and the chemical composition of granite and laterite aggregate which involved SEM testing, EDX testing and Distribution Test.

SEM-EDX for Morphology of Aggregates

The experiments of Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray spectroscopy (EDX) enables the chemical properties to be laid out as one of the analytical technique to reflect the chemical characterization. A total of 200 g of laterite aggregate was prepared for the test. The aggregate is being coated with gold or titanium to let the energy of the electron beam of the electron microscope eject a core shell electron and dissipates some of the absorbed energy which make the outer shell electron to fill its place and release different energy. This energy is emerged in the form of x-ray which has spectrum based on the origin. This will allow the compositional analysis of laterite aggregate that excited the energy source. The position of the peaks in the spectrum identifies the elements where the intensity of the signals will correspond the element concentration.

Chemical Composition of Aggregates

Beranang Laterite aggregates colour from slightly orange to dark brown as shown in Figure 1.1, due to their existences in tropical forest and the climate affect the colour of the Beranang Laterite aggregates as they go through a weathering process as they are exposed to alternate drying and wetting that affect the properties of the Beranang Laterite aggregates. Laterite aggregates are rich in secondary oxides of aluminium, iron or both and highly weathered. In Table 3 below, contains the chemical composition that is present in the Beranang Laterite aggregates.

Table 1: The Chemical Composition of Laterite aggregate used in tests

Oxide Components	Percentage Limits
Silica	22 to 48
Hermatite	20 to 40
Alumina	30 to 53
Silica-Sesquioxide Ratio	0.28 to 0.95

The chemical characteristics of the Beranang Laterite aggregates can be determined by conducting the composition of chemical in the aggregate to identify whether the Beranang Laterite aggregates are suitable to act as partial replacement aggregate in a concrete mix. Same experiments were conducted on granite aggregates and the results were compared to laterite aggregate.

RESULT AND DISCUSSION

Morphology of Aggregates

Figure 3 shows the granite and Beranang Laterite aggregate shape. The surface texture of Beranang Laterite aggregate is rougher compared to granite aggregate which is smoother.

Figure 3: Laterite aggregate (Left) and granite aggregate (right)

For the morphological of the aggregates, it can be identified by their exterior aspects in the figure above such as surface texture, colour and shape. The surface texture of Beranang Laterite aggregate is rougher compared to granite aggregate which is smoother. The morphology of aggregate contributes significant impact to the overall concrete performance because most of the constituents of concrete mix is from aggregates. This is supported by the previous researchers Richard Ohene Asiedu (2017), as it had stated that the strength of concrete is contributed by the strength of aggregate indirectly. It is included that the surface texture and the shape of the aggregate that is helping in term of bonding the constituents of concrete mix altogether and indirectly give higher strength to the concrete mix.

In addition, the sharp and rough shape of aggregates will bond better as compared to the round shape of aggregates in the concrete mix. This is highlighted by Sneka, M.Nirmala and Dhanalakshmi (2018) stated that the rougher the aggregate is, it will contribute more to the bonding inside the concrete matrix. Thus, it is important to have a rough and hard texture of concrete with sharp and rough surface in order to improve the bonding inside the concrete mix and give significant impact on the overall concrete performance (Yan Feng *et. al.*, 2019). The direct impact on the aggregate properties upon the performance of concrete has been discussed in previous researches (Folagbade & Osadola, 2019). The electron image of granite aggregate and Beranang Laterite aggregate morphology that identifies the both aggregates physical characteristics were shown in Figure 4 and 5. Both of them showed the presence of the roughness surface; however, for Beranang Laterite, the surface of the aggregate is rougher as compared to the granite aggregate.

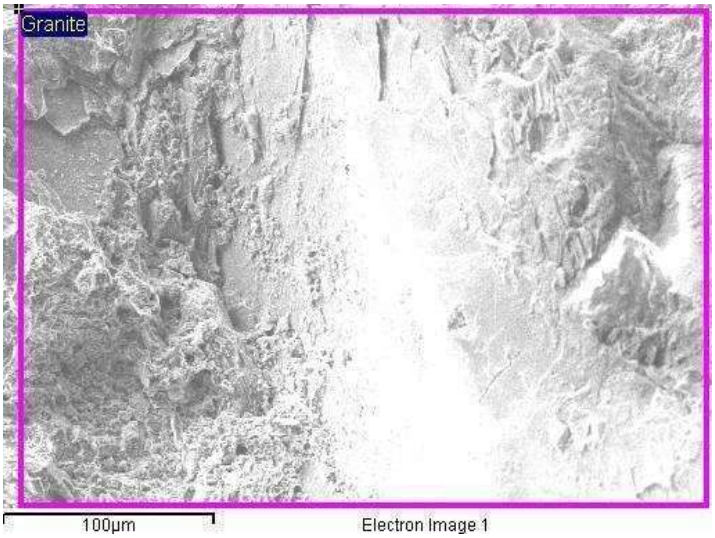

Figure 4: The morphology of granite aggregate.

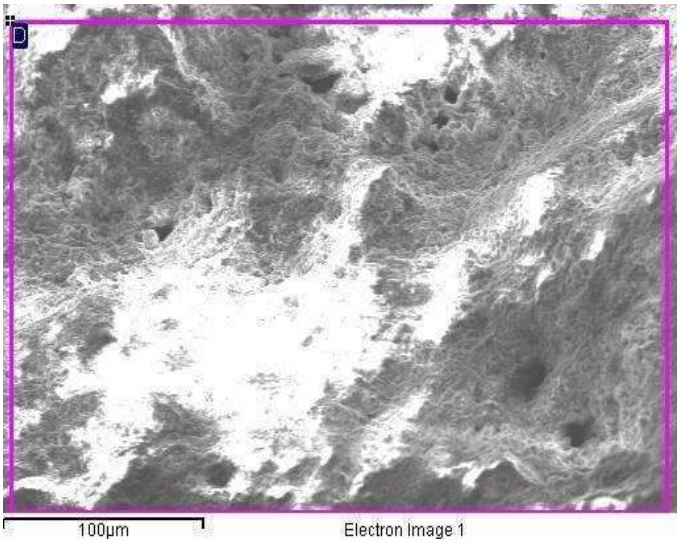

Figure 5: The morphology of laterite aggregate.

Chemical Composition of Aggregates

There will be some differences in the chemical compositions because the origin of both aggregates are different. Granite aggregates are the igneous rocks that produced from a cooled magma which are very rich in quartz and feldspar. Whereas the laterite aggregate is produced from a weathering process where the aggregate has been exposed to the extreme weather cycles which are very rich in secondary oxides iron and aluminium. Usually the laterite aggregate is available in the tropical regions where the sunlight is quite rough and has a lot of rainfall. That is why the laterite aggregate is always known as the aggregate that is highly weathered.

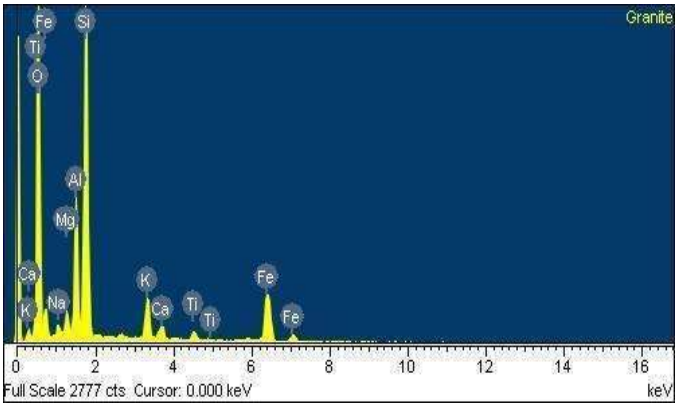

Figure 6: The chemical composition of granite aggregate

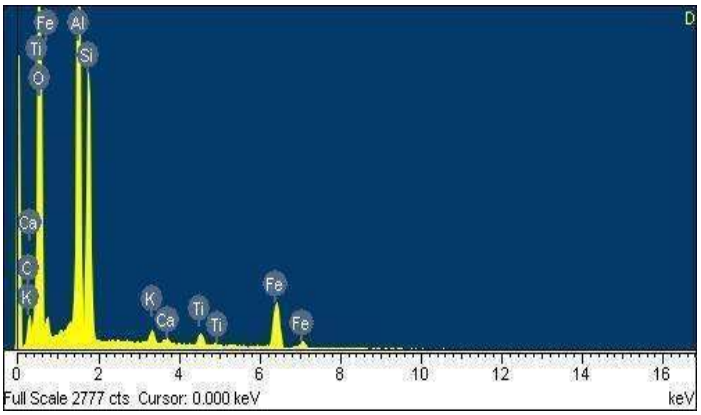

Figure 7**:** The chemical composition of Beranang laterite aggregate

Table 2: Chemical composition or elements of granite aggregate and Beranang laterite aggregate

ELEMENT	***GRANITE***	***LATERITE***
O	58.01	62.24
C	0	1.32
MG	1.26	0
AL	6.91	15.98
SI	17.76	11.38
K	3.01	0.77
CA	0.92	0.23
TI	0.96	0.90
FE	10.28	7.18
NA	0.89	0
TOTAL (%)	**100**	**100**

From Table 2 above, there are some similarities in the chemical composition between granite aggregate and laterite aggregate such as iron (Fe), calcium (Ca), silicon (Si), aluminium (Al), titanium (Ti) and potassium (K). The uncommon chemicals that laterite aggregate does not have are magnesium (Mg) and sodium (Na), which present in granite aggregate

CONCLUSION

Based on the results on the chemical characteristics of granite and Beranang laterite aggregate, it can be concluded that the major elements of the granite are oxygen, silica and ferum whereas for Beranang laterite aggregate are oxygen, aluminium and silica. Thus this experiments shows the similarity of both aggregates' chemical properties to be used in the construction industry.

ACKNOWLEDGEMENTS

The authors would like to thank Infrastructure University Kuala Lumpur under the IUKL Internal Research Funds (IIRF) for this research project.

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International Journal of Infrastructure Research and Management
Vol. 11 (1), June 2023, pp. 96 - 118

THE INFLUENCE OF INTERNAL SYSTEM AND EXTERNAL ENVIRONMENT OF USER SATISFACTION AND ITS EFFECT ON ELECTRONIC WORD-OF-MOUTH IN ONLINE GROCERY IN MALAYSIA

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ABSTRACT

This study explored the antecedents of electronic word-of-mouth (e-WOM) in online grocery shopping in Malaysia. In addition to the DeLone & McLean Information Systems (IS) Success Model and Unified Theory of Acceptance and Use of Technology (UTAUT) theory, the research investigated the relationships between internal system and external environment and user satisfaction in the online grocery industry. The quantitative research method was used to verify the research model. The sample included 532 valid respondents from the Klang Valley, Malaysia. The analysis methods used include Descriptive Statistics, Cronbach's Alpha, Multiple Regression, and Bootstrap Analysis. The results suggest that internal system factors (information quality, system quality and service quality) and external factors (social influences and facilitating conditions) significantly and positively affect both user satisfaction and e-WOM. The findings contributed to theory advancement in e-commerce studies, and to the knowledge of online grocery business. This study also paved the way for researchers to determine future research topics that must be explored. Managerial implications from the findings also provide advice, from which managers can proactively take action to increase the odds of success in consumers' e-WOM behaviour. Limitations of the study include the small sample size and lack of other aspects of e-WOM. So, increasing the sample size and adding some other factors could be implications for future research directions.

Keywords:
E-WOM, User Satisfaction, System Quality, Service Quality, Social Influence, Facilitating

INTRODUCTION

The development of new media cannot be separated from the emergence of the Internet and the World Wide Web due to the globalization of information technology. Social media is a media where users can easily participate in, and share and create messages. It includes blogs, social networks, online wikis or encyclopaedias, and virtual forums, including virtual worlds (Zhuravskaya et al., 2020). According to Nuseir (2019), electronic word of mouth (e-WOM) is a form of marketing communication that contains positive or negative statements made by potential customers, customers or former customers about a product or company, which is made available to many people or institutions through the medium of the Internet. In the online world, there are various ways in which consumers can exchange information.

Internet users can conduct e-WOM through a variety of online channels, including blogs, microblogs, e-mails, consumer review sites, forums, virtual consumer communities and social networking sites (Dahka et al., 2020). In reflecting on the feeling of pleasure and satisfaction from consumers, it will be directly proportional to a positive image view of the product or brand. E-WOM and the Internet have enabled the emergence of new forms of communication platforms that can better empower providers and consumers, enabling them to share information and opinions from both Business-to-Consumer, and from Consumer-to-Consumer (Muritala, 2021).

Today's e-WOM is becoming more and more technically complex and challenging, which exposes e-commerce operations to even more complex constraints. System values can be regarded to be the basis that forms and influences human behaviour. Obviously, researchers are only focused on internal factors when studying e-WOM such as information quality, system quality and service quality

(Fraj & Martinez, 2017; Huma et al., 2020). Unfortunately, there is limited focus on the influence of external factors (Aakash & Aggarwal, 2019). As such, both internal and external environmental factors should be included in an e-WOM study as a whole instead of just as a sum of their parts. External factors are always playing a crucial role in propagating new technology (Xu et al., 2019). The social influence and facilitating conditions as the external problems are widely touted for constraint analysis, greatly limiting the researcher's capability in modelling and resolving constraints to achieve consumer satisfaction.

Existing research methods have long been blamed for their limitations in modelling and communicating constraints, including the inability to cope with other-related mediating and moderating precedence constraints and difficulty to evaluate and communicate inter-dependencies at the field of e-grocery level (Yan et al., 2018; Ismagilova et al., 2020). As the level of competition in the Malaysian e-grocery market continues to rise, it is critical for Malaysian e-grocery businesses to gain a better understanding of their customers in order to expand their market share (Martín et al., 2019).

Therefore, assessing e-WOM has been an increasing topic of interest to business owners in order to create new strategic marketing plans as the influence of many internal and external factors on consumer satisfaction in Malaysia have been found to be underwhelming nowadays (Choi et al., 2019). In the course of the investigation, the present study endeavoured to illuminate this irregularity by building up a single integrated conceptual framework to connect and simultaneously inspect the connections between internal factors, external factors, user satisfaction and e-WOM in an online grocery platform.

Therefore, this study aimed to utilize classifications of user satisfaction and e-WOM involvement proposed by past studies. This coordinated e-WOM model would provide the foundation for building a consensual model, which may better clarify these relationships. In this regard, the current writing focuses on investigating the relationships between the antecedents and consequences of e-WOM from both internal and external perspectives.

OBJECTIVES

The objectives of the study can be summarised as follows:

- RQ1: Do internal factors (system quality and service quality) affect user satisfaction?
- RQ2: Do internal factors (system quality and service quality) affect electronic word-of-mouth?
- RQ3: Do external factors (social influence and facilitating conditions) affect user satisfaction?
- RQ4: Do external factors (social influence and facilitating conditions) affect electronic word-of-mouth?
- RQ5: Does user satisfaction affect electronic word-of-mouth?

LITERATURE REVIEW

Electronic Word-of-Mouth

According to Hennig-Thurau et al. (2015), the Word of Mouth (WOM) theory has shifted from physical or face-to-face interaction to e-WOM allowed by the Internet as a result of advancements in Internet technology. E-WOM is defined as any favourable or negative comment made about a product or firm via the Internet by future, current, or previous customers. Customers utilise e-WOM to share their thoughts and expertise about products and services they have purchased on platforms including social media, blogs, online forums, online reviews, and chat rooms. WOM information can be generated by e-WOM elements such as ideas and recommendations, ratings and reviews, and forums and communities in the context of e-commerce.

Some studies characterise e-WOM behaviour as a broad category that includes a wide range of human activities including e-commerce, internet shopping, the hotel and tourism sectors, and so on (Levy & Gvili, 2020; Nguyen, 2021; Antony, 2017; Harris & Prideaux, 2017). The e-WOM behaviour scale has been used in several studies as a one-dimensional model to measure overall e-WOM engagement. For instance, previous research has explored the factors that encourage customer engagement with e-WOM from the perspective of information characteristics, consumer behaviour, consumer motives, and technological and social factors (Yusuf et al., 2019).

Bogdan and Nicoleta (2018) studied the influence of emotional commitment, high-sacrificial commitment, and contentment on consumers' word-of-mouth regarding an online store; and Verma and Yadav (2021) investigated the impact of e-WOM on the hotel sector. Similarly, Fred and Robert (2017) conducted research with the goal of determining the types of tourists who submit reviews, the motives for posting reviews, the types of sites on which they post reviews, and the message characteristics. This study, however, concentrated on online grocery because this segment has been one of the fastest growing economic sectors in recent years (Lin et al., 2021).

System Quality

System quality refers to a set of business operations focused on information system processing in order to simultaneously fulfil quality criteria and objectives (Fazlollahtabar and Kazemitash, 2021). Indeed, the existence of such aspects is very important to guarantee that customers can easily and successfully use the targeted website, and accordingly, share their experience of using the website and their intention to reuse it as well (Tarhini et al., 2019).

Customers' opinions of system quality are similar to other types of e-commerce products or services, especially when it comes to an online platform to pick vegetables, meats, or dairy products (Oncini et al., 2020). According to the study, consumers would be happy if they notice a rather user-friendly system features while browsing or engaging with e-grocery websites (e.g., system flexibility, the content of the database, site navigation, and visual attractiveness).

The quality of a system has been demonstrated to impact a user's endorsement and approval in general. This means that when the IS and product system quality are good, customers see it as being of more value, believing it will enhance their productivity or efficiency, and they will recommend it to others. Byrd et al. (2016) recently verified that system quality is one of the most important predictors of e-WOM, and that the system may also help an organization's product sales volume grow once a system user has recommended it to others. According to Negasha et al. (2017), enhancing user e-WOM requires a system design that incorporates all system aspects. When developing a web-based customer service system, he discovered that interactivity and accessibility are the most significant predictive characteristics of e-WOM. The following are hypothesised as a result of the preceding discussion:

H1: System quality has a positive relationship with user satisfaction.
H2: System quality has a positive relationship with e-WOM.

Service Quality

The service quality of any website could be related to the extent of the website's reliability, trustworthiness, empathetic elements, and security as well as its ability to provide customers with a high degree of customisation and interactivity (DeLone and McLean, 1992; Gao et al., 2015; Parasuraman et al., 1988). In fact, as discussed by Demir et al. (2021), having an adequate level of service quality on the website represents a prerequisite to establishing the customer's trust and any problem in providing customers with reliable service and speedy responses will lead to customer's distrust.

Consumers today are increasingly aware of the services that businesses provide, and a good service provides them with a positive experience. Clients will be satisfied and may become good recommenders if they have a positive experience with the service provided (Nobar & Rostamzadeh, 2018). With rising competition among businesses that use e-commerce and the online channel to interact with their customers, the idea of e-service quality has become a more important aspect because it can help with customer satisfaction and retention.

Prior research has demonstrated a strong and positive relationship between service quality and e-WOM. As an illustration, Roy et al. (2020) studied the impact of e-WOM stimuli and e-WOM reactions on perceived service quality and online recommendations. In line with this, Uslu (2020) quantified that the quality of a restaurant's service has a good and significant impact on e-WOM. In another study, Zhang et al. (2016) investigated the impact of restaurant service quality, atmosphere, and food on customers' online comments. The impact of positive e-WOM on restaurant popularity through online channels has been discovered. Therefore, this study evaluated the following hypotheses in the context of e-grocery in Malaysia based on the argument:

H3: Service quality is positively related to user satisfaction.
H4: Service quality has a positive relationship with e-WOM.

Social Influence

Social influence was defined by Venkatesh et al. (2003) as the extent to which an individual perceives how important others believe that he or she should apply the new system. Over the prior literature, the role of social factors has been largely argued as one of the key determinants of the individual's decision to adopt new systems (Fan et al., 2020). Indeed, a customer is more likely to be influenced by the thoughts and opinions of their reference group (i.e., friends, colleagues, family, and relatives) especially for the more novel technologies (i.e., online shopping) that the customer has less experience with and information (Shareef et al., 2019; White et al., 2019; He & Harris, 2020; Gavilan et al., 2018).

Social aspects have long been recognised as having an influence on consumer satisfaction. The majority of previous research has concentrated on subjective standards in an attempt to grasp the essence of social influence, but the results have been mixed, and the impact on technology has been unequal. Social influence has a large impact on user satisfaction only in necessary circumstances,

The study by Rita, Oliveira and Farisa (2019) indicated that there is a relationship between service quality and satisfaction of consumers in an online shopping environment. Service quality would improve consumers' confidence level. In addition, Hole, Pawar and Khedkar (2019) stated in their research that online retailers provided different ways of communication channels to their consumers in order to increase the communication between the consumers and themselves. The various communication and adaptable channels are provided for the convenience of their consumer to contact

the online retailer in order to increase consumer satisfaction. Therefore, it is important for an online retailer to put more emphasis on these criteria. Online retailers have to cover both pre-purchase and also post-purchase stages, especially focussing on service quality. Thus, by improving e-service quality, it could help increase consumer satisfaction (Zhou et al., 2019).:

According to Hamilton et al. (2019), consumers' tendency to speak about their purchases with their friends has a beneficial influence on their views of products and services, prompting them to either buy the same brand or avoid certain brands in order to stand out from their peers. Power and Philips-Wren (2019) likewise concluded that social media friend pressure is faster and more extensive than face-to-face pressure.

As a result of the discussion above, the following hypotheses were proposed:

H5: Social influence is positively related to user satisfaction.
H6: Social influence has a positive relationship with e-WOM.

Facilitating Conditions

Facilitating conditions is the degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system including knowledge, capabilities, and consumer resources (Venkatesh et al., 2012). If all the online grocery platform infrastructure and knowledge that is needed in using available, and also if there is support for using the platform, the user satisfaction and intention of e-WOM on their online grocery will be increased.

E-commerce may be able to add to the vast list of enabling conditions, particularly in the area of food and beverage (Waitz, et al., 2018). E-grocery, for example, might advertise numerous discounts, keyless systems, incentives, and active promotions that customers can take advantage of by downloading the app (Fikar et al., 2019). Furthermore, the e- grocery's mobile payment capability would promote consumers and hotels to do direct booking transactions. As a result, these metrics are expected to have a favourable impact on consumer satisfaction and behaviour.

Results from a study in Pakistan by Khan, Yu, Hameed, Khan and Waheed (2018) found empirical evidence that facilitating conditions have a positive impact on physicians' online recommendations to adopt e-prescribing. In Saudi Arabia, Alwahaishi and Snášel (2017) observed a positive relationship between facilitating conditions and the online referral of e-commerce, and later the UTAUT2 study by Susanto, Abdullah, Rela and Wardi (2017) in Indonesia also confirmed this relationship.

Based on the points discussed above, the following were hypothesised:

H7: Facilitating conditions is positively related to user satisfaction.
H8: Facilitating conditions has a positive relationship with e-WOM.

User Satisfaction

Arora and Narula (2018) defined satisfaction as the summary psychological state resulting when the emotion surrounding disconfirmed expectations is coupled with a consumer's prior feelings about the consumer experience. Quan et al. (2020) similarly defined satisfaction as the contentment of the customer with respect to his or her prior online purchasing experience. Accordingly, we can conceptualize satisfaction as a holistic experience based on the overall evaluation of online grocery shopping experiences.

User satisfaction, according to Rahi and Ghani (2019), leads to behavioural tendencies. When a client makes a repeat purchase, especially when the customer's perceived enjoyment is positive, it influences the chance of a repurchase. There is a relationship between consumers' emotional states and their desire to share their experiences with others, according to existing studies on interpersonal effects. For example, Jeong and Shawn (2017) find a connection between user satisfaction and e-WOM intentions. Both Casalo et al. (2018) and Neelamegham and Jain (2019) conducted studies that back up the premise that there is a connection between satisfaction and e-WOM intentions. Technological innovation has definitely accelerated the sharing concept by developing e-WOM as a platform for e-grocery stores (Barbiero, 2022). Based on these points, the following hypothesis is developed:

H9: User satisfaction has a positive relationship with e-WOM.

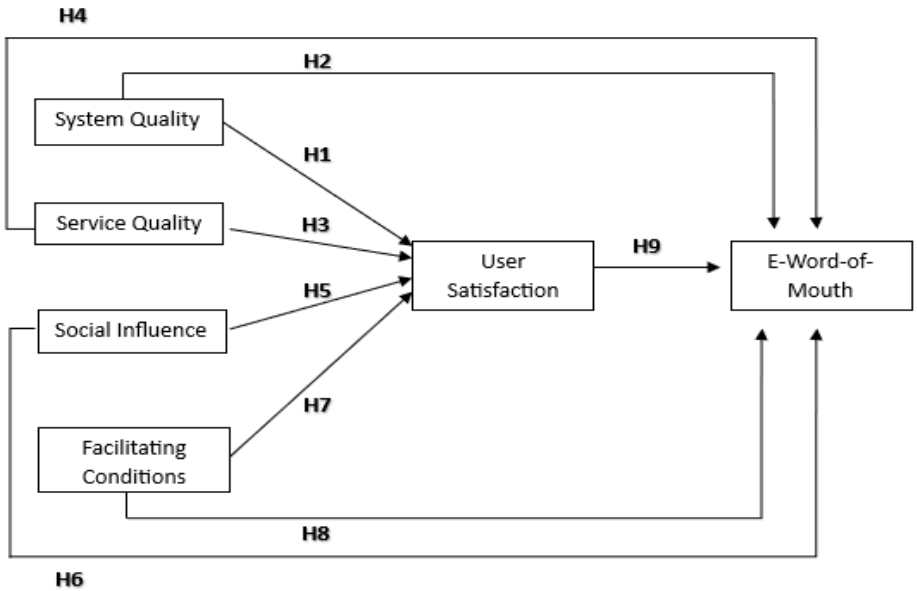

Figure 1: Research Framework

RESEARCH METHOD

Sample and data collection

This research study used the explanatory technique. The study is explanatory in that it investigated the causes and consequences of internal and external factors on user satisfaction, as well as their impact on electronic word-of-mouth (e-WOM) among Malaysian e-grocery customers. An explanatory study could provide answers to these types of questions. The population of interest in this research investigation was Malaysian consumers who had actual purchase experience of online groceries within the last six months of the point of contact. They are sampled from the geographic area with the highest population in Malaysia which is the Klang Valley.

There are four types of general techniques that should be taken into account when establishing the minimal sample size for this study: a) a minimum number for a specific situation or research type; b) sample size-to-item ratio; c) sample size utilised in similar previous studies; and d)

a sample size calculator (Jiang et al., 2016). As such, it was concluded that a minimum sample size of 525 was needed.

Questionnaires were used as the primary data collection method in this study. The questionnaires had been constructed beforehand and distributed online fully through email and social media platforms (incl. WhatsApp and Facebook) to the respondents in the Klang Valley. The sampling was done using a non-probability purposive sampling technique which involved 532 respondents in total. The demographic information was identified.

Measures

The consumers' satisfaction, e-WOM behaviour, internal system factors and external environmental factors were also identified using the Likert scale in providing a quantitative measure for the constructed questions. Five Likert-type items were used, which are Strongly Disagree (1), Disagree (2), Neutral (3), Agree (4), and Strongly Agree (5). There were 42 items tested which covered system quality, service quality, service quality, facilitating conditions, user satisfaction, brand image and electronic word-of-mouth.

The analyses of the study consisted of descriptive analysis, reliability analysis and factor analysis which were carried out using SPSS (Statistical Package for the Social Sciences) version 26 and followed by Partial Least Squares Structural Equation Modeling (PLS-SEM) method using SmartPLS version 3.0. A descriptive analysis was conducted to analyse the demographic information of this study which included residential area, age, gender, marital status, education, race, occupation and income.

A reliability analysis was done to estimate the consistency of the data and Cronbach's alpha was used as the index for the reliability of the data (George & Mallery, 2018). As suggested by Chan and Idris (2017), the Cronbach's alpha of the reliability test should have a minimum value of 0.6 for the data to be considered consistent in the early stage of research. These data were further analysed with factor analysis to analyse the satisfaction, e-WOM behaviour, internal system factors and external environmental factors of all respondents.

RESULTS AND DISCUSSIONS

Respondent Profile

Table 1 indicates the respondent's background. Based on the survey, the majority of the respondents were female (56.3 percent), aged between 21 to 30 years old (63.9 percent) and most were Chinese (66.9 percent). In terms of education and income levels, the majority of the respondents (82.7 percent) had a bachelor's degree. The majority (75.2 percent) of the respondents work as an associate or executive officer.

The demographic information also gave some insights into the profile of Malaysian consumers who bought groceries online using e-grocery apps or platforms (89.7 percent). They can be clustered into different groups based on the frequency of e-grocery purchases with the majority (38.2 percent) buying 7-9 times a week.

Table 1: Respondents' Demographic

Field	Categories	Frequency	Percentage (%)
Gender	Male	232	43.6
	Female	300	56.4
	Total	**532**	**100.0**
Age	20 years and below	13	2.4
	21 to 30 years	340	63.9
	31 to 40 years	92	17.3
	41 to 50 years	83	15.6
	51 years and above	3	0.6
	6.0	1	0.2
	Total	**532**	**100.0**
Ethnicity	Malay/Bumiputera	104	19.5
	Chinese	356	66.9
	Indian	63	11.8
	Others	9	1.7
	Total	**532**	**100.0**
Location	Kuala Lumpur	178	33.5
	Petaling	267	50.2
	Klang	41	7.7
	Gombak	18	3.4
	Hulu Langat	6	1.1
	Sepang	6	1.1
	Kuala Langat	6	1.1
	Putrajaya	10	1.9
	Total	**532**	**100.0**
Level of Education	Less than High School	7	1.3
	High School Graduate	31	5.8
	Undergraduate Degree	440	82.7
	Postgraduate Degree	40	7.5
	Others	14	2.6
	Total	**532**	**100.0**
Employment Status	Student	67	12.6
	Associate/Executive	400	75.2
	Managerial/Professional	50	9.4
	Self-Employed	6	1.1
	Retired	2	0.4
	Homemaker	2	0.4
	Others	5	0.9
	Total	**532**	**100.0**

Frequency of using e-grocery (in a week)	1 - 3	107	20.1
	4 - 6 times	142	26.7
	7 - 9 times	203	38.2
	10 times and more	80	15.0
	Total	**532**	**100.0**

Respondents' Usage Pattern via Frequency Analysis

Table 2 showed the summary of the types of e-grocery platforms used by respondents. *HappyFresh* was recorded with the highest number of purchases among the applications. A total of 347 or 65.2 percent of the respondents bought groceries online via the *HappyFresh*'s online platform within the past six months of the survey. *Lotus Groceries* was in the second position with 310 (58.3%) respondents using this platform. This is followed by *Mydin Online* (274 respondents or 51.5%), *Jaya Grocer* (257 respondents or 48.3%) and also other e-grocery platforms (25 respondents or 4.7%).

Table 2: Preferred E-grocery Apps among Consumers

Ranking	Types of E-Grocery Platform Used	Frequency	Percentage (%)
1	HappyFresh	347	65.2
2	Lotus Groceries	310	58.3
3	Mydin Online	274	51.5
4	Jaya Grocer	257	48.3
5	Others	25	4.7

Measurement model reliability

This process was to ensure that the questionnaire used was reliable (consistent) and valid (measure the right things). The preliminary evaluation used 36 items adapted from various literature. The cut-off or threshold points where factor loading must be greater than 0.5, composite reliability must be greater than 0.7 and average variance extracted (AVE) must be greater than 0.5 (Shrestha, 2021; Nasution et al., 2020). Table 3 shows the results of the measurement model evaluation.

Factor loading and composite reliability were generated as a check on the reliability of the measurement items. The reliability test is used to basically test the overall consistency of the measurement items. High reliability of a measure will produce similar results under consistent conditions (Chan & Idris, 2017). According to Nasution, Fahmi and Prayogi (2020) and Shrestha (2021), a measure or a measurement item can be claimed as reliable if its factor loading value is greater than 0.5 and also its composite reliability value is greater than 0.7.

Cronbach's alpha reliability was used to obtain the α values (coefficient alpha) for all the study variables. This is to measure how well the items measuring a concept work together as a set (Chan & Idris, 2017). Cronbach's alpha is used to compute the average intercorrelations among the items measuring the concept. The closer the coefficient to 1.0 the better (Chan & Idris, 2017). Table

3 shows that all the values of factor loading and composite reliability exceeded the recommended values of 0.5 and 0.7, which satisfy the reliability at item and construct levels.

Table 3: Evaluation of Measurement Model

Construct	**Item**	**Loadings (>0.50)**	**Composite Reliability (>0.7)**	**AVE (>0.5)**	**Cronbach's Alpha (>0.6)**
Electronic Word-of-Mouth	EWOM1	0.638	0.794	0.527	0.657
	EWOM2	0.770			
	EWOM3	0.729			
	EWOM4	0.663			
	EWOM5	0.672			
	EWOM6	0.620			
User Satisfaction	US1	0.729	0.842	0.517	0.765
	US2	0.733			
	US3	0.759			
	US4	0.746			
	US5	0.619			
	US6	0.695			
System Quality	SQ1	0.851	0.906	0.762	0.844
	SQ2	0.880			
	SQ3	0.888			
	SQ4	0.565			
	SQ5	0.727			
	SQ6	0.675			
Service Quality	SERQ1	0.704	0.850	0.586	0.764
	SERQ2	0.802			
	SERQ3	0.791			
	SERQ4	0.760			
	SERQ5	0.507			
	SERQ6	0.695			
Social Influence	SI1	0.744	0.868	0.625	0.797
	SI2	0.866			
	SI3	0.871			
	SI4	0.662			
	SI5	0.657			
	SI6	0.643			
Facilitating Conditions	FC1	0.698	0.829	0.548	0.727
	FC2	0.754			
	FC3	0.736			
	FC4	0.772			
	FC5	0.792			
	FC6	0.613			

Assessment of Structural Model

A structural model evaluation was undertaken to test the research hypotheses. To assess the structural model, the path coefficient and t-value of the model were generated by applying PLS algorithm and bootstrapping procedure with 5,000 resamples as recommended by Mei et al. (2018). Figure 4 is the path model extracted from the SmartPLS 3.0 programme. The R^2 for the endogenous variables in this study are 0.333, which indicates that the internal factors and external factors explained the 33.3

percent of the variance in user satisfaction, and 0.179, which indicates that user satisfaction explained the 17.9 percent of the variance in electronic word-of-mouth (see Table 4).

Table 4: The R^2 Values of Endogenous Constructs

Predictor Construct	Target Construct	R^2
SQ, SERQ, SI, FC, US	EWOM	0.179
SQ, SERQ, SI, FC	US	0.333

Note: EWOM-Electronic Word of Mouth, US-User Satisfaction, SQ-System Quality, SERQ-Service Quality, SI-Social Influence, FC-Facilitating Conditions

Basically, the Stone-Geisser's Q^2 value was obtained to evaluate the predictive relevance of the PLS path model (Janadari et al., 2016). The blindfolding procedure was executed in order to obtain both the Q^2 values for user satisfaction and electronic word-of-mouth. According to Davadas and Lay (2017) and Ogiemwonyi et al. (2020), a Q^2 value which is larger than zero would indicate the predictive relevance of the path model.

For the present study, the Q^2 value of 0.158 for user satisfaction and the Q^2 value of 0.073 for electronic word-of-mouth were obtained after the blindfolding procedure (see Table 5). Both values were greater than zero which mean that the PLS path model for the present study could be accepted and supported in term of its relevancy in studying this phenomenon. Thus, the exogenous variables showed the capability to predict the endogenous variable.

Table 5: The Q^2 Values of the Path Model

Endogenous Construct	Q^2	Predictive Relevance
EWOM	0.073	Yes
US	0.158	Yes

Note: EWOM-Electronic Word of Mouth, US-User Satisfaction

Direct Effect

In order to examine the relationship between the study variables, bootstrapping the direct effect with 5,000 resamples was implemented (Preacher and Hayes, 2019). In order to conclude that a relationship is significant, the t-value of that direct path must be greater than 1.645 (Hair et al., 2018). The detailed bootstrapping analysis report is depicted in Table 6 below.

The bootstrapping analysis shows that the direct effects of H1, H2, H3, H4, H5, H6, H7, H8 and H9 are significant. The values for system quality ($\beta = 0.256$, $t = 3.519$, $p < 0.00$), service quality ($\beta = 0.254$, $t = 2.694$, $p < 0.00$), social influence ($\beta = 0.152$, $t = 5.543$, $p < 0.00$) and facilitating conditions ($\beta = 0.116$, $t = 5.543$, $p < 0.00$), were found significantly and positively related to user satisfaction.

Besides that, the values for system quality ($\beta = 0.042$, $t = 3.306$, $p < 0.00$), service quality ($\beta = 0.154$, $t = 2.452$, $p < 0.00$), social influence ($\beta = 0.150$, $t = 2.828$, $p < 0.00$), facilitating conditions ($\beta = 0.124$, $t = 2.628$, $p < 0.00$) and user satisfaction ($\beta = 0.131$, $t = 2.633$, $p < 0.00$) were also found to have significant and positive relationship with e-WOM.

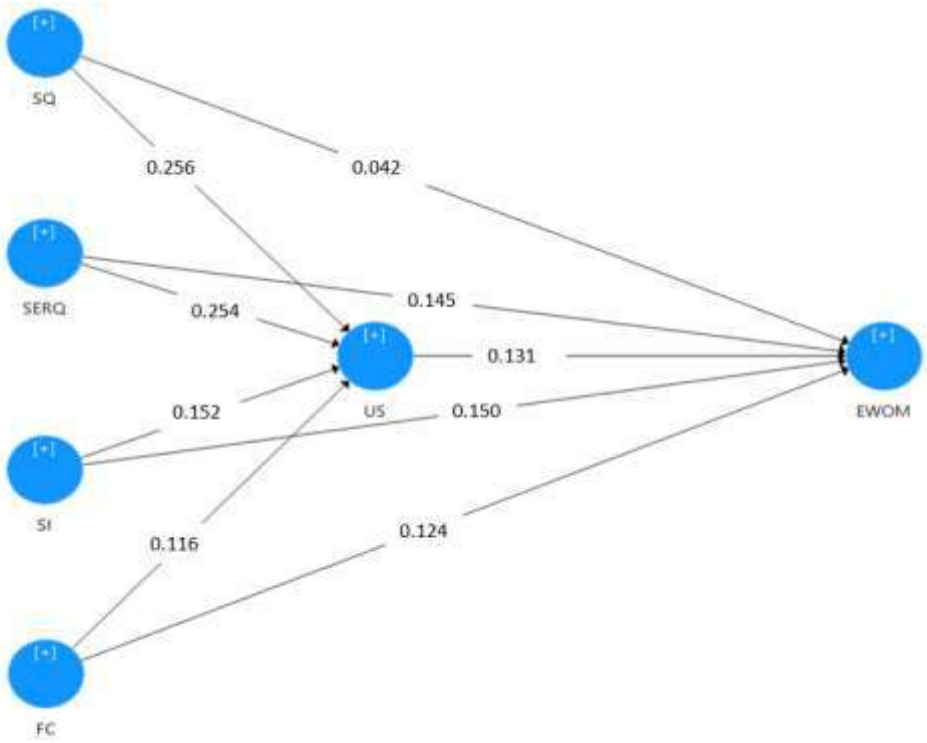

Figure 2: SmartPLS Direct Path Model

Table 6: Results of Direct Effect Testing

Hypothesis	Path	Coefficient	SD	t-value	F^2	Supported
H1	SQ -> US	0.256	0.043	3.519	0.027	Yes
H2	SQ -> EWOM	0.042	0.045	3.306	0.020	Yes
H3	SERQ -> US	0.254	0.043	2.694	0.014	Yes
H4	SERQ -> EWOM	0.154	0.051	2.452	0.013	Yes
H5	SI -> US	0.152	0.038	6.724	0.078	Yes
H6	SI -> EWOM	0.150	0.051	2.828	0.002	Yes
H7	FC -> US	0.116	0.046	5.543	0.062	Yes
H8	FC -> EWOM	0.124	0.055	2.628	0.015	Yes
H9	US -> EWOM	0.131	0.050	2.633	0.014	Yes

Note: EWOM-Electronic Word of Mouth, US-User Satisfaction, SQ-System Quality, SERQ-Service Quality, SI-Social Influence, FC-Facilitating Conditions

Discussion of the Findings

System Quality (SQ) Affect User Satisfaction (US) *[H1: Supported]*

This study confirmed that system quality significantly and positively affects user satisfaction. The results of the bootstrap analysis confirmed the strong effect of system quality on user satisfaction in the online grocery industry. This finding supports a previous study by Nazief and Mardiana (2019) that assessed end-user satisfaction as an impact of the system quality, information quality and top management support, upon the perceived usefulness of technology utilization. Thus, e-grocery platforms should focus on the quality of the system used by consumers including upgrading the utility, availability, reliability, adjustment and response time. Furthermore, it is important to focus on the time taken to process sales transactions and purchase transactions.

Similarly, a study by Anjarwati and Apollo (2018) showed that system quality, information quality and perceived usefulness have a significant influence to user satisfaction. According to the result of the coefficient value of the overall model, the highest influence was shown by the influence of system quality on user satisfaction. This finding also is consistent with the data analysis technique using SEM that explained that system quality affects use and user satisfaction (Santa et al. 2019). System quality in this context refers to the measure of desired characteristics of a system consisting of usability, availability, reliability, adaptability and response time.

A technical system that meets the customer needs such as simplicity, security and flexibility is positively associated with user satisfaction (Correia et al., 2020). Such system quality values are likely to influence user satisfaction among those who use online shopping stores. As such, an online platform which has high system quality may lead users to have more positive user satisfaction towards using and purchasing groceries online. This high system quality could determine and drive a satisfied user towards purchasing groceries online which ultimately helps in protecting the environment.

Within the specific context of online grocery purchases, Phuong and Trang (2018) analysed 256 responses collected from Vietnamese consumers and concluded that value orientations (including system quality) are significantly related to consumer satisfaction with online grocery delivery for protecting the environment. Similar results were generated in Steg et al., (2017) study that analysed responses of 112 Dutch respondents and found that system quality is significantly related to feelings of convenience and personal comfort to reduce household energy, money and time consumption. If this is applied to this study, those e-retailers that provide services for grocery shopping via the internet are those with high system quality that provides an overall customer experience which meets customers' expectations. However, this result contradicts the studies of Meinie (2018), and Sebetci and Çetin (2020) which found that system quality does not significantly affect users' satisfaction with the software.

System Quality (SQ) Affect E-Word of Mouth (EWOM) *[H2: Supported]*

The quality of a system provided by technology apps is perceived as credible and influential by customers (Dastjerdi et al., 2019). The interactivity of technology systems ensures that relevant and undistorted customer reviews and opinions are on the website. Hence, the customers' perception of the overall quality of the website can be increased when e-WOM systems are reciprocal and responsive. As such, the degree of the highest and lowest system for a technological device will be evaluated and will be a push factor for e-WOM. For instance, if a person thinks that a technology app is good and benefits future generations, they tend to spread word of mouth online.

Oppong et al. (2019) applied this to their study and found that those who use apps with a high level of system quality with a strong emphasis on the benefits of using online grocery apps for themselves personally and also for the environment will likely purchase through these apps without hesitation. This is because they can feel the positive outcomes from such e-WOM (recommendations)

in buying these products. Previous studies have found significant relationships between system quality and e-WOM (Susilowati & Sugandini, 2018; Chao et al., 2020; Yildiz, 2017).

There are previous studies that found system quality directly influences e-WOM on purchasing grocery products online. This is evident in household grocery consumption, in the studies of Martin et al. (2019) and Singh (2021) pertaining to grocery e-commerce. On the other hand, the tendency for users to discontinue usage, complain and pass negative comments on mobile services is high, especially when the quality of the system is rather poor (Oppong et al., 2021).

Service Quality (SERQ) Affect User Satisfaction (US) ***[H3: Supported]***

This finding is consistent with the DeLone & McLean IS success model where good service quality leads to customer satisfaction. This study confirmed that service quality significantly and positively affects user satisfaction. This means that a person who leans towards online quality services or responsiveness is likely to have a positive attitude towards using e-grocery platforms that help protect and preserve the environment. This is because they are accepting of new lifestyles or trends in society with regard to taking care of the environment.

The research outcome aligns with Alzoubi and Inairat (2020) customer satisfaction framework that reveals that a strong service quality orientation could influence user satisfaction on commercial transactions conducted electronically on the internet. Service quality directs the satisfaction and behaviour of people and can be related to specific focuses of functioning, as well as forming interrelated structures. In brief, service quality can be thought of as a cognitive process or a way of thinking related to human satisfaction in socially advantageous ways (Whitley et al., 2018).

Some researchers have similar findings such as Obeidat et al. (2012) and Alshurideh et al. (2017) who developed a linkage between service quality and both customer satisfaction and customer loyalty but not that much link between perceived service quality effect on both customer satisfaction and customer delight. Arora and Narula (2018), for example, confirmed the impact of service quality on customer satisfaction and customer loyalty. In addition, Lai and Nguyen (2017) examined the factors affecting customer satisfaction and customer loyalty in the telecommunications industry. Both scholars found that service quality, assurance, responsiveness, reliability, empathy and tangibility have some effects on and have positive relationships with both customer satisfaction and customer loyalty.

Service Quality (SERQ) Affect E-Word of Mouth (EWOM) ***[H4: Supported]***

Service quality has a positive and significant influence on customer satisfaction which makes the firms more competitive in the market. Quality service or customer service in the online grocery business is an important antecedent to e-WOM. Basically, those who receive a high level of service quality are those accepting of the social trend of spreading the word in an online environment. The process of transmitting messages is fast where everyone can share their opinion and experience related to products with complete strangers who are socially and geographically dispersed.

This finding aligns with other studies which also confirmed service quality affects electronic word-of-mouth. Specifically, service quality is linked with the spread of word behaviour (Geiger et al., 2017). Zhang found that service quality has a direct impact on citizens' online word of mouth, particularly complaint intention. Their results were based on the analysis and comparison between 29 cities in China. This result aligns with many studies related to technology acceptance as well where customer support especially service quality will influence a person's intention to share positive or negative opinions about a technology (Vahdat et al., 2021).

Technological advancements are benefiting businesses and consumers alike, but they are also causing challenges for the public sector. Today's consumers are surrounded by the very best service quality. A wealth of new tools and technologies are available to companies to help them

deliver seamless customer service and support. As these technologies become more readily accessible and available, consumers are becoming increasingly accustomed to these experiences. This results in exceptional service quality expectations, and heaping judgement of public consumers to voice and share via the internet.

Social Influences (SI) Affect User Satisfaction (US) ***[H5: Supported]***

It is true that social influence can affect customer satisfaction in the context of e-commerce. The results obtained fully supported the theoretical model which analyses individual social interactions from a behavioural and technological point of view according to a study by Hassan and Ahmad (2018). In other words, a satisfaction held by a person (self-concept) is subject to external influences. The external influences here refer to the influences from those people that are important, including opinion leaders.

Within the specific context of online grocery purchases, Urevna (2021) investigated the social influences towards the satisfaction of consumers after using e-grocery apps among 182 homeowners. Social influences are having a significant influence on the homeowners' satisfaction with the importance of using technology-driven apps to benefit themselves (utility costs) and also society as a whole.

Basically, satisfaction towards the environment is influenced by many aspects. But for sure one of the factors could be social influences. A normal human being is not isolated from others. As they are living in a group and society, social influences are expected. Social influences can affect different aspects of our daily lives. The culture, ways of thinking, beliefs, etc. are the aspects that can be changed through external forces instead of just via self-learning. Social agents play major and important roles in shaping satisfaction in society. Family members are very crucial in shaping and changing a family member's satisfaction. Schools and workplaces can be venues that influence our thoughts. Some religious organizations can have considerable influence on user satisfaction.

Social Influences (SI) Affect E-Word of Mouth (EWOM) ***[H6: Supported]***

The result of this study found that social influence affects e-WOM. It is true that the surrounding environment shapes our satisfaction and subsequently our behaviour to generate online remarks. In other words, word of mouth through the internet spread by a person is subject to external influences. The external influences here refer to the influences from those people that are important, including opinion leaders.

Social influences impact both general and e-word of mouth as found in many previous studies. The results of this study are in accordance with research conducted by Litvin et al. (2018) who studied the retrospective view of electronic word-of-mouth in hospitality and tourism management; and Huete-Alcocer (2017) who conducted a literature review of word of mouth and e-WOM and its implications on consumer behavior. Other studies include those by Zhang et al. (2021) who studied the impact of interpersonal closeness and social status on electronic word-of-mouth effectiveness and Utarsih (2018) who looked at the influence of social factors and word of mouth against buying interest. Social influences are found as an important driver of e-WOM. The result is consistent with a study by Loureiro et al. (2018) that revealed that social influences are influencing e-WOM on fashion brands on retail websites. A similar study by Ismagilova et al. (2019) found that the relationship between social influences and e-WOM is significant.

Furthermore, this study confirmed that social influences significantly and positively affect e-WOM. This means that the individual consumer's decision on the purchase of groceries via online applications is not solely based on themselves. It is partly influenced by others surrounding them. Peer pressure or peer influence is the direct influence on individuals who are influenced to follow their peer's e-WOM. The result aligns with UTAUT which explains users' intention and usage

behaviour of a particular new technology. This theory included the environmental factors in explaining new technology usage behaviour (Taherdoost, 2018). The UTAUT has been tested in many technology acceptance studies and has high predictive powers in various studies.

Facilitating Conditions (FC) Affect User Satisfaction (US) ***[H7: Supported]***

This study confirmed that facilitating conditions significantly and positively affects user satisfaction. This means that external push factors lead to positive user satisfaction towards the importance of recommendations and subsequently on e-WOM on online grocery. A number of previous studies have confirmed that facilitating conditions is a significant factor leading to consumers' approval of a technology user (Tandon et al., 2018; Shahid, 2018; Alalwan, 2020).

The external influences here refer to the resources/facilities to use online grocery platform (OGP) technology, the knowledge of OGP technology usage, OGP technology compatibility with other techniques used, and the availability to get help from others when having difficulties using OGP technology. Customer satisfaction is viewed as a result of a comparison between consumption, expectation and experience, and customer satisfaction is achieved when the final deliverable (i.e., experience) is up to expectations. Customer satisfaction plays a pertinent role in online shopping, as it influences consumer decisions on whether to continue with online shopping. Therefore, customer satisfaction is taken as a dependent variable in this study.

The original facilitating conditions variable is from the UTAUT. However, this variable only links usage behaviour and not any other user satisfaction variables. This means that with given facilitating factors, the satisfaction from the purchase of groceries online can be changed among consumers. This study is consistent with Moser (2019) which investigated German households pertaining to their online grocery purchase. Facilitating conditions such as special discounts and educational programmes play an important role in stimulating satisfaction after purchasing green products for the purpose of the betterment of the environment.

Facilitating Conditions (FC) Affect E-Word of Mouth (EWOM) ***[H8: Supported]***

This study confirmed that facilitating conditions significantly and positively affect e-WOM. It is very common that external factors or motivations will serve as a push factor for the new trend in disseminating information. The result aligns with UTAUT which explains users' intention and usage behaviour of a new technology. This theory includes the environmental factors in explaining user behaviour (Taherdoost, 2018).

This research is supported by research conducted by Yogesh et al. (2017) which found that contextual factors (facilitating conditions) had direct effects on attitude and behavioural intention (to spread the words online). This suggests that individuals may associate importance to the facilitating conditions such as help desks and training programs as well as to the experiences of other individuals in using the technology. Hence, organizations should consider providing adequate infrastructural facilities and proper training to users so that they can be positively inclined to use new technologies.

For instance, managers can organize users' in-house and vendor-based IS/IT training (Behrendt et al. 2021) and help desks on premises or at vendor sites to offer technical assistance to aspiring users (Ostrowski, 2021; Mitropoulos et al., 2021; Iancu, 2020). Managers may proactively manage its organizational and technical infrastructure that may be used by individuals by organizing forums for sharing best-use practices, instituting front-runners who are enthused about new technologies and eventually are able to generate positive word-of-mouth, or planning counter-measures for any negative feedback.

User Satisfaction (US) Affects E-Word of Mouth (EWOM) ***[H9: Supported]***

This study confirmed that user satisfaction significantly and positively affects electronic word-of-mouth. The satisfaction systems towards e-commerce have a considerable effect on forming consumers' negative or positive opinions. A person who has positive satisfaction with using an online grocery marketplace will likely tell people about the particular product or service they use on social media. This result aligns with the technology acceptance model (TAM) that influence behaviour (Vahdat, 2021). In other words, satisfaction held by a person (positive or negative) will be reflected in his or her behaviour. For instance, if consumers are satisfied with the product or service, they will share their thoughts that it is good online, and want to encourage others to try it. This theory helps to link satisfaction and online word of mouth.

Within the specific context of online grocery purchase behaviour, Miswanto and Angelia (2018) found that consumer satisfaction can encourage consumers to tell others about their satisfaction, and it creates word of mouth. Pleasant experience when shopping creates customer satisfaction, so customer satisfaction encourages word of mouth. Larry (2017) also found in his study that customer satisfaction encourage consumers to express their satisfaction to others. Moreover, this can encourage consumers to come or go shopping again at the same online marketplace.

This reveals that positive user satisfaction in using online platforms is the antecedent to electronic spread of words. When consumers feel that it is beneficial and useful to use web applications, it will lead to the purchase of groceries products via the digital service. Otherwise, they will not bother to purchase such items, especially at a higher price. In inculcating the appropriate customer satisfaction strategy among students, it can be introduced as a new subject in university for business studies and be made a compulsory subject to pass before students can proceed to the next higher level of education. If this satisfaction can be achieved by consumers from the start of the e-retail businesses, then more consumers will express e-WOM online to spread to others. Once it is successful, this will not be easy to change. To shape this user satisfaction, it is advisable for business owners to improve any direct impact factors such as employee competence, reliability, product innovation, price and convenience, to name a few.

CONCLUSION

Through a survey of 532 respondents in the Klang Valley, the proposed research model was tested. The results confirm nine hypotheses. Two internal factors (system quality and service quality) and two external factors (social influence and facilitating conditions) were found to influence both user satisfaction and electronic word-of-mouth. User satisfaction was also found to have a positive impact on e-WOM behaviour.

This research study emphasises factors that are appropriate in the e-WOM online grocery shopping context and proposes a productive research direction for future researchers, especially, that when consumers assume that online purchasing on the e-grocery platform has high system quality, reliable service quality, social influence, and perceive facilitating conditions, they are likely to be satisfied with the online stores which makes it likely for e-WOM to occur. In summary, sellers and system providers of online grocery businesses play a crucial role in ensuring positive experiences of consumers, resulting in customers' satisfaction and the sharing of their experiences with the product or service directly with friends, family members or co-workers.

One of the major limitations of this study was that it used a cross sectional survey design and not a longitudinal survey design. This is due to limited time and resources. Another limitation is that this study covered only an urban area instead of both urban and rural areas. The survey or data collection covered the Klang Valley only, an area consisting of Kuala Lumpur and parts of Selangor. Even though it can be claimed that the respondents are representative because they originate from

different states but these current urban dwellers possess different characteristics from those living in rural areas. Basically, those who are staying and working in the Klang Valley have higher socioeconomic status and purchasing power compared to those in the rural areas. Third, user satisfaction as a concept is still considered a relatively new construct in this field of study. Hence, limited literature is available to generate quality questionnaire items for measuring this construct. User satisfaction is measured by four general items adapted for the present study. This general user satisfaction might not be enough to measure overall satisfaction towards the online grocery industry.

Future research studies can use a longitudinal survey design as it would be more appropriate for studies where the perceptions of the respondents are collected more than once. Further, a qualitative examination of e-grocery consumers from urban versus rural behaviours can be explored in the emerging Malaysian market. Since this study covers purely the specific aspects of e-services, it will be an effective practice if further research could be conducted in the future on non-services and e-services as well in terms of examining new factors which may impact customer satisfaction including a discussion of the latest technological changes.

MANAGERIAL IMPLICATIONS

The instrument for this study was designed to capture useful information in explaining consumer profiles and behavioural patterns related to online grocery shopping. This information provided insights into the frequency of grocery purchases online. Their characteristics had been demographically compiled and the overall consumer profile for Malaysia was defined. Additionally, the purchase reasons or motivations of these internet businesses were also recorded. The main reason was cost saving in utility expenses instead of protecting the environment. It is obvious that people are still not fully aware of the environmental benefits of using these online platforms. When consumers do not believe in the importance of protecting the environment, the purchase of groceries online (which requires paying more) will be minimal.

With this information, both government agencies and non-governmental organizations (NGOs) can utilize it for their subsequent planning to deal with this issue. It helps in identifying and segmenting household purchaser groups for more targeted education and promotional programmes to be formulated. This study hopes to contribute to a wider understanding pertaining to the acceptance and purchase via e-commerce platforms. Information such as the usage duration and reasons for purchase of online groceries provide insights into the impact of these programmes on society. Such information can be used as new input into similar or different programmes that are being planned by the government and industry. It is in the government's and industry's interests to have more information on the behavioural pattern that helps reduce utility costs and promote community sustainability by reducing the negative impact of electricity production.

For environmental agencies, they can make use of the findings to encourage consumers to be responsible towards the environment, especially in their daily purchases. Various educational or training programmes can be used to educate and to encourage more environmentally friendly consumption patterns. Such training can also teach consumers how to differentiate between green and non-green products, which will help in protecting the environment. Since the facilitating conditions influence the online purchase of groceries, environmental agencies can suggest to the government to introduce incentives or conveniences that can be provided to consumers. All these facilitating conditions might not influence or change the environment but it helps with online grocery purchases as there are push factors.

For industry and marketing practitioners, this study provides information necessary in explaining what promotes and hinders e-WOM. For instance, information on individual differences and purchase reasons will help marketers segment their market and formulate various strategies to cater to various consumer groups. Their purchase motivations need to be identified to promote

acceptance of effective purchase. With good segmentation, different marketing strategies can be implemented for various groups in line with the objectives.

Furthermore, the different types of apps used by the respondents give an indication of which online grocery stores are popular among consumers. For instance, *HappyFresh* is the top app downloaded by the majority of the respondents. With such information, the industry and marketers can actually strategize their sales and marketing plans. For instance, they may look into the reasons why other similar apps store are less in demand by consumers so that promotions can be arranged.

The industry can plan in terms of their allocation of funds for upgrading their online platforms to be more user-friendly. For online grocery apps, more allocation for system enhancements and improvements may be needed to optimize profit. For other aspects, appropriate strategies can be planned either to improve the products to generate more sales or to remove certain functions that are not necessary. This information serves as an important input for strategic decision making by top management on the operation aspect.

For marketers, appropriate promotions can be planned as well using sales data recorded. With good promotion strategies, the industry can minimize its losses due to unsold stocks. Different incentives or bundle promotions can help boost the sales of the not-so-popular items so that cash can be generated. Since environmental factors are found to influence the purchase decision, marketers can include some of these factors such as incentives for recommendations from other consumers, and training and education programmes in promoting e-grocery software apps.

The outcome of this study enables companies to formulate appropriate strategies to tap into the market. Companies will be aware of the facilitating factors from the environment that may help to promote the purchase and usage of e-grocery software programs that can be downloaded onto a mobile device. For instance, the industry can provide more educational and after-sales service programmes to reduce some of the risks that consumers may face when using such software apps. It is hoped that the insights from this study can help provide detailed information on e-WOM in Malaysia. The research results generated from this study might be useful in planning strategically the promotion, adoption and acceptance of online grocery purchase in the community.

THEORETICAL IMPLICATIONS

One of the most popular information systems success assessment models that resulted in highly significant contributions in the research literature is the DeLone and McLean IS success model conceptual model (IS Success model). As Gable, Sedera and Chan (2019) note, the development of IS success models, such as the DeLone and McLean model, has been an important contribution toward the improved understanding of IS management. However, one of the strongest criticisms about the IS Success model is the lack of external factors quality among variables. According to Pitt, Watson and Kavan (2018), there is a danger that researchers will mismeasure IS effectiveness if they do not include in their assessment criteria a measure of IS service quality. The external environment, such as social influence, brand image, time consumption and facilitating conditions, is an important part of information systems departments; thus, the external environment is a critical measure of information system effectiveness (Van Dyke et al., 2017). As a result, in order to measure information system effectiveness properly, many researchers believed that external factors should be included in the IS success model as a success measure (Kettinger & Lee, 2017; Myers et al., 2017; Pitt et al., 2020).

Having realised the importance of external factors, this study outlined that not only is the internal system quality important to the users, but the external factors of the system should be considered as well. In response to the calls of other researchers that criticized the original model, and due to the advent and growth of Internet-based e-services, this study decided to add social influence and facilitating conditions to their new model as an important dimension of IS success noting the significance of user satisfaction in the online grocery industry. Therefore, a proposal for an integrated

model of e-WOM and its antecedents in online grocery was developed, based on the Unified Theory of Acceptance and Use of Technology 2 (Venkatesh et al.,2012) and the Information Systems success model (DeLone & McLean, 1992).

This research provides significant theoretical contributions. First, this research confirms the relationship between the variables studied in this research, namely motivation, entrepreneurial leadership, organisational agility, competitive advantage, and firm performance of SE. The study examines all the constructs as described in the research model. With the lack of similar research that has been done on e-grocery applications, this research fills the gaps that exist in e-grocery research. In addition, the role of other variables on the firm performance of SE was also covered, taking into account the global pandemic situation. One of the main differentiators of this research is the chosen unit of analysis, that is, the SE. Results in this study show several hypotheses turned out to have different results compared to the similar hypotheses that use commercial firms as the unit of analysis, which contributes to drawing a clearer line between SE and for-profit organisations. This research is responding to the research agendas that have been described by previous researchers, which called for more research regarding SE in the face of unstable external conditions, especially SE from developing countries, that involve motivation, and distinguish between social and economic factors of firm performance.

The results of this study only represent conditions of e-WOM at the specific time of this research, unlike a longitudinal study. Moreover, this study only focused on e-WOM in the Klang Valley as the unit of analysis and took samples from respondents based in several Klang Valley cities. Consequently, the results only represent e-WOM in those specific areas. The results might differ when a larger sample is taken from e-WOM in different states of Malaysia or when the study includes urban and rural areas as well. It might be interesting for future research to adopt the research model and study e-WOM from different developing and developed regional states and then compare and examine whether geographical aspects create different results. Because the existence of e-WOM can potentially be the solution to internal and environmental influences, and while this study only focuses on the relationship between system quality, service quality, social influence and facilitating conditions, it might be helpful if future researchers conduct studies on several other constructs that might influence e-WOM to improve its social and economic performance, especially in a competitive and unstable environment. Also, future studies can focus more on other specific industry-related to e-WOM.

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International Journal of Infrastructure Research and Management
Vol. 11 (1), June 2023

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ISSN 2811-3608