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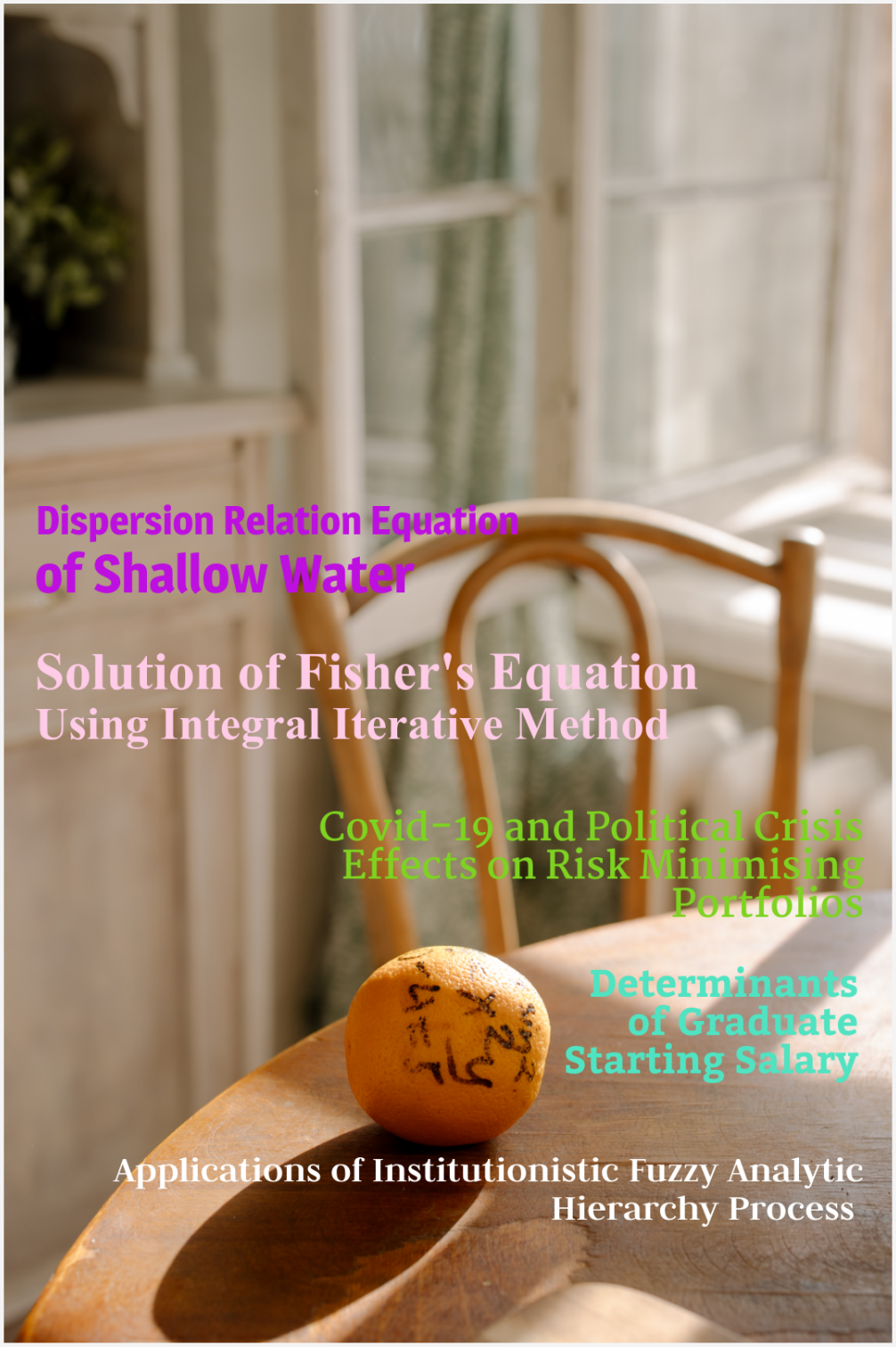

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Bagi pihak editorial, saya mengucakan Syabas dan tahniah kepada pasukan penerbitan yang berusaha keras untuk menghasilkan makalah Mathematics in Applied Research. Saya juga ingin mengambil kesempatan ini untuk menyampaikan ucapan terima kasih khas buat dua editor yang akan meninggalkan kita untuk bersara iaitu;

- Profesor Madya Dr. Nur Azlina Abd Aziz
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semoga kecemerlangan perkhidmatan yang ditunjukkan oleh kedua editor-editor ini akan menjadi pendorong kepada editorial board yang seterusnya.

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for all the dedications and

Happy Retirement

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Contents

RISK MINIMIZATION FOR A PORTFOLIO USING MEAN ABSOLUTE DEVIATION AND CONDITIONAL VALUE-AT-RISK
Iylia Lyiana Rahim, Mohd Azdi Maasar, Siti Ayuni Mohd Jamil, and Nur Anis Mohd Aziz **1**

FORECAST THE PROFITABILITY OF ISLAMIC BANKS IN MALAYSIA BASED ON ISLAMIC INTERBANK RATE
Husnul Adib bin Muhamad Amin, Muhammad Alif bin Izani, Ahmad Aqil bin Ahmad Azam, Muhammad Hazim bin Nordin and Nur Amalina Shafie **5**

COVID-19 AND POLITICAL CRISIS EFFECTS ON RISK MINIMISING PORTFOLIO FOR MALAYSIA'S STOCK MARKETS USING MEAN-CVAR OPTIMIZATION MODEL
Amera Katrina Kornain, Mohd Azdi Maasar, Nur Aisyah Nadhirah Ismanazir ,and Najwa Roseli **9**

DISPERSION RELATION EQUATION OF SHALLOW WATER: WAVELENGTH ESTIMATOR
Nor Azni Shahari, Maizatur Najihah Azlan, Siti Nuramyra Mohd Abd Razak and Nurain Nadhirah mohamad **13**

ROOT FINDING FOR NON LINEAR EQUATION BASED ON IMPROVEMENT NEWTON'S METHOD
Nor Azni Shahari, Maizatur Najihah Azlan, Siti Nuramyra Mohd Abd Razak and Nurain Nadhirah mohamad **18**

NUMERICAL APPROXIMATION OF BLASIUS EQUATION USING DAFTARDAR-GEJJI AND JAFARI METHOD
Mat Salim Selamat, Siti Maisarah Ramli, Rafika Rasuli and Nadia Mohamad **23**

AN INTUITIONISTIC FUZZY ANALYTIC HIERARCHICAL PROCESS (IFAHP) APPROACH IN SOLVING THE MARKETING PLATFORM SELECTION PROBLEM
Nor Faradilah Mahad, Nur Aishah Mohd Ali, Fadilah Jamaludin and Nur Sabrina Ridzwan **25**

THE APPLICATION OF INTUITIONISTIC FUZZY ANALYTIC HIERARCHY PROCESS (IFAHP) IN SOLVING PERSONNEL SELECTION PROBLEM
Nor Faradilah Mahad, Che Siti Zaiznena Che Mat Zain, Saffiya Nuralisa Mohd Syahidan and Nur Qamarina Hanim Saidin **29**

SOLUTION OF FISHER'S EQUATION USING INTEGRAL ITERATIVE METHOD
Mat Salim Selamat, Nursyaqila Zakaria, Siti Aisyah Mahrop, and Raja Iryana Puteri Raja Azman Shah **33**

MIXED INTEGER PROGRAMMING APPROACH FOR MINIMIZING TRAIN DELAY
Nurul Liyana Abdul Aziz, Nur Faqihah Jalil, Faridatul Azra Md Shamsul and Zaliyah Abbas **36**

SOLVING LANE-EMDEN EQUATION USING PADE APPROXIMATION METHOD
Najir Tokachil, Muhammad Aiman, Noramira Farzana, and Nurul Shahira Aimie **40**

DETERMINANTS OF GRADUATE STARTING SALARY: A CASE STUDY
Nora Mohd Basir, Yong Zulina Zubairi, Rohana Jani and Diana Abdul Wahab **43**

KMV MODEL IN PREDICTING SOVEREIGN DEBT DEFAULT
Siti Mahani Isman, Nur Faiqah Mohd Ngasri, Nazihah Misman, and Norliza Muhamad Yusof **46**

TEMIMI AND ANSARI METHOD FOR SOLVING QUADRATIC RICCATI DIFFERENTIAL EQUATION
Mat Salim Selamat, Nurul Syafiqah Tajudin, Wahyu Hidayah Roslan and Nur Aqilah Rosli **50**

AWARENESS ON PREVENTION OF CORONAVIRUS (Covid-19): A CASE STUDY OF INTERNSHIPS STUDENTS IN UNIVERSITI TEKNOLOGI MARA CAWANGAN NEGERI SEMBILAN
Syafiqah Samat, Nurdia Azlin Ghazali, Nur Hidayah Mohd Razali and Noor Aisyah Idris **52**

MIXED INTEGER PROGRAMMING APPROACH FOR MINIMIZING TRAIN DELAY

Nurul Liyana Abdul Aziz*, Nur Faqihah Jalil, Faridatul Azra Md Shamsul and Zaliyah Abbas
Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA (UiTM) Cawangan Negeri Sembilan, Kampus Seremban, Persiaran Seremban Tiga/1, 70300 Seremban, Negeri Sembilan.
*Corresponding author: liyana511@uitm.edu.my

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1. Introduction

In the high technological world of today, transportation maintains up with the advancement of human existence and culture. Additionally, it has improved economic structure by speeding up the distribution of economic growth. Malaysia is another nation that offers commuter rail services. The only provider of train commuter services in Malaysia is Keretapi Tanah Melayu, which offers services in the Klang Valley, Penang, Perak, and Johor. Railway service that is readily accessible to the general public is perfect for reducing highway traffic, especially in congested areas, and promoting environmentally responsible and sustainable growth. Malaysians prefer taking the train over driving because it saves them money while avoiding traffic and allows them to reach their destination on time. However, because of the technical fault could impair the railway network, the railway firm frequently encounters unforeseen issues, such as sudden changes to the original schedule (Alwadood et al., 2015).

This study is related to public scheduling problems and focuses on train scheduling problem. The aim of this study is to estimate the delay time from Padang Besar to Sungai Petani by using mixed integer programming. The train scheduling problem will be modelled as mixed integer programming and the data will be taken from the KTM Berhad website. By using Microsoft Excel, the model was used to estimate the delay time. At the end of this study, a new train schedules was proposed.

2. Methodology

This study explains the method and formulation of the train schedule using the mixed integer programming model to minimize the train delay by rescheduling the present timetable of KTM Berhad at station Padang Besar to Sungai Petani. Several essential steps are conducted during the study to achieve the result discussed in the following subsections.

At many stations, certain trains arrive or depart with delayed services, which is known as a call delay. The impact of a train delay is larger for passengers. Since each train precisely left from Padang Besar to Sungai Petani, the goal of this study is to determine the entire delay time of each train at several stations involved. The exact time of the train left is used to calculate the delay time.

The MIP model formulation is as follows:

To minimize

$$\sum_{p \in T} z_{v_p} \tag{1}$$

The objective function (1) is to calculate the minimum sum of delay experienced by all trains when it reaches their final destination.

Subject to

$$y_r^I \geq x_r^I + \Delta_r \ , r \in \mathrm{E} \tag{2}$$

Constraints (2) describe the minimum running time for each of the train event.

$$y_r^I \geq x_{r+1}^I \ , r \in R_p \ , p \in T : k \neq v_p \tag{3}$$

Constraints (3) shows that each train event must departed and arrive as the original schedule so that the next train could departed as scheduled.

$$y_r^I \geq x_r^I + \Delta_r \ , r \in E \tag{4}$$

Meanwhile constraints (4) indicate that train need to depart and arrive as the scheduled time.

$$x_r^I \geq x_r^S \ , r \in E \tag{5}$$

Constraints (5) represent the reschedule departure time should not be earlier than the scheduled departure time.

$$x_r^I \geq x_r^A \ , r \in E : x_r^S > 0 \tag{6}$$

Constraints (6) shows that departure time must depart as being schedule even though there might be a distraction.

$$y_r^I \geq y_r^A \ , r \in E : x_r^S > 0 \tag{7}$$

Constraints (7) indicates that arrival time must depart as being schedule even though there might be a distraction.

$$y_r^I - y_r^S \leq z_r \ , \ r \in E \tag{8}$$

Constraints (8) define total delay of trains as the divergence in between reschedule and original schedule arrival times.

$$T_i = y_r^A - x_r^A \tag{9}$$

Constraints (9) describe about the real travel time of train after arrived at the final destination.

3. Results and Discussions

To analyse the compatibility and ability of the model developed in the previous part, the model was further tested on a real KTMB train schedule. Table 1 contains seven different trains departed from Padang Besar to Sungai Petani with a different departure time. This data was taken from KTM Berhad website. The origin station is Padang Besar while the end station is Sungai Petani.

Table 1: Train schedule from KTM Berhad website

STATION \ TRAIN	2955	2959	2963	2965	2969	2971	2975
Padang Besar	12:35	14:35	16:35	17:35	18:35	19:35	21:35
Bukit Ketri	12:47	14:47	16:47	17:47	18:47	19:47	21:47
Arau	12:54	14:54	16:54	17:54	18:54	19:54	21:54
Kodiang	13:00	15:00	17:00	18:00	19:00	20:00	22:00
Anak Bukit	13:13	15:13	17:13	18:13	19:13	20:13	22:13
Alor Setar	13:18	15:18	17:18	18:18	19:18	20:18	22:18
Kobah	13:29	15:29	17:29	18:29	19:29	20:29	22:29
Gurun	13:39	15:39	17:39	18:39	19:39	20:39	22:39
Sungai Petani	13:52	15:52	17:52	18:52	19:52	20:52	22:52

The delay data was then successfully computed by using the current original train schedule. The first train's delay data was collected from Mohd Zulkifli and Noordin (2016). However, the delay interval for other six trains were created at random based on the relative delay time from the first train.

Table 2: New train schedule

STATION \ TRAIN	2955	2959	2963	2965	2969	2971	2975
Padang Besar	12:38	14:38	16:38	17:38	18:38	19:38	21:38
Bukit Ketri	12:50	14:50	16:50	17:50	18:50	19:50	21:50
Arau	12:57	14:57	16:57	17:57	18:57	19:57	21:57
Kodiang	13:03	15:03	17:03	18:03	19:03	20:03	22:03
Anak Bukit	13:16	15:16	17:16	18:16	19:16	20:16	22:16
Alor Setar	13:21	15:21	17:21	18:21	19:21	20:21	22:21
Kobah	13:32	15:32	17:32	18:32	19:32	20:32	22:32
Gurun	13:42	15:42	17:42	18:42	19:42	20:42	22:42
Sungai Petani	13:55	15:55	17:55	18:55	19:55	20:55	22:55

Table 2 shows the new train schedules from Padang Besar to Sungai Petani. This schedule has been calculated based on overall results in Table 3 that containing the average of actual departure time and actual arrival time.

Table 3: Overall result of total train's delay

Train	Average actual departure time	Average actual arrival time	Actual travel time	Original travel time	Total delay
2955	0:02:15	0:02:52	1:22:30	1:17:00	0:05:30
2959	0:02:13	0:02:47	1:22:11	1:17:00	0:05:11
2963	0:02:14	0:02:50	1:22:26	1:17:00	0:05:26
2965	0:02:16	0:02:51	1:22:07	1:17:00	0:05:07
2969	0:02:15	0:02:52	1:22:30	1:17:00	0:05:30
2971	0:02:18	0:02:56	1:22:43	1:17:00	0:05:43
2975	0:02:17	0:02:56	1:22:43	1:17:00	0:05:43

4. Conclusions

KTM trains has experienced several difficulties including delays. This study focused on modelling the train scheduling problem as a mixed integer programming. This mixed integer programming model consists of eight constraints and the objective function is to minimize the summation of the delay experienced by all trains when it reaches their final destination. Hence, by using the model, the total delay for seven trains (Train No. 2955, 2959, 2963, 2965, 2969, 2971, and 2975) are estimated involving nine stations starting from Padang Besar to Sungai Petani. In addition, this study assumed that all trains experienced delay since the first station

The findings revealed a significant time difference between the current train schedule and anticipated journey times on all trains. Based on the estimated total delay, this study proposed a new schedule for all seven trains from Padang Besar to Sungai Petani. This new schedule will help KTM to revise their current schedule in order to reduce the waiting time of the passengers.

Table 3 shows the average of actual departure time, average of actual arrival time, actual travel time, original travel time and the total delay for every train that departure from Padang Besar to Sungai

Petani. As for trains No. 2971 and No. 2975, it recorded the highest delay time which is 5 minutes 43 seconds and followed by other trains which are No. 2955 and No. 2969 with their total delay time is 5 minutes 30 seconds, each. The least delay time for this destination belonged to train No. 2965 with recorded delay time 5 minutes and 7 seconds.

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