





e-PROCEEDINGS

of The 5th International Conference on Computing, Mathematics and Statistics (iCMS2021)

4-5 August 2021 Driving Research Towards Excellence





e-Proceedings of the 5th International Conference on Computing, Mathematics and Statistics (iCMS 2021)

Driving Research Towards Excellence

Editor-in-Chief: Norin Rahayu Shamsuddin

Editorial team:

Dr. Afida Ahamad Dr. Norliana Mohd Najib Dr. Nor Athirah Mohd Zin Dr. Siti Nur Alwani Salleh Kartini Kasim Dr. Ida Normaya Mohd Nasir Kamarul Ariffin Mansor

e-ISBN: 978-967-2948-12-4 DOI

Library of Congress Control Number:

Copyright © 2021 Universiti Teknologi MARA Kedah Branch

All right reserved, except for educational purposes with no commercial interests. No part of this publication may be reproduced, copied, stored in any retrieval system or transmitted in any form or any means, electronic or mechanical including photocopying, recording or otherwise, without prior permission from the Rector, Universiti Teknologi MARA Kedah Branch, Merbok Campus. 08400 Merbok, Kedah, Malaysia.

The views and opinions and technical recommendations expressed by the contributors are entirely their own and do not necessarily reflect the views of the editors, the Faculty or the University.

Publication by Department of Mathematical Sciences Faculty of Computer & Mathematical Sciences UiTM Kedah

TABLE OF CONTENT

PART 1: MATHEMATICS

	Page
STATISTICAL ANALYSIS ON THE EFFECTIVENESS OF SHORT-TERM PROGRAMS DURING COVID-19 PANDEMIC: IN THE CASE OF PROGRAM BIJAK SIFIR 2020 Nazihah Safie, Syerrina Zakaria, Siti Madhihah Abdul Malik, Nur Baini Ismail, Azwani Alias Ruwaidiah	1
Idris	
RADIATIVE CASSON FLUID OVER A SLIPPERY VERTICAL RIGA PLATE WITH VISCOUS DISSIPATION AND BUOYANCY EFFECTS Siti Khuzaimah Soid, Khadijah Abdul Hamid, Ma Nuramalina Nasero, NurNajah Nabila Abdul Aziz	10
GAUSSIAN INTEGER SOLUTIONS OF THE DIOPHANTINE EQUATION $x^4 + y^4 = z^3$ FOR $x \neq y$ <i>Shahrina Ismail, Kamel Ariffin Mohd Atan and Diego Sejas Viscarra</i>	19
A SEMI ANALYTICAL ITERATIVE METHOD FOR SOLVING THE EMDEN- FOWLER EQUATIONS Mat Salim Selamat, Mohd Najir Tokachil, Noor Aqila Burhanddin, Ika Suzieana Murad and Nur Farhana Razali	28
ROTATING FLOW OF A NANOFLUID PAST A NONLINEARLY SHRINKING SURFACE WITH FLUID SUCTION <i>Siti Nur Alwani Salleh, Norfifah Bachok and Nor Athirah Mohd Zin</i>	36
MODELING THE EFFECTIVENESS OF TEACHING BASIC NUMBERS THROUGH MINI TENNIS TRAINING USING MARKOV CHAIN Rahela Abdul Rahim, Rahizam Abdul Rahim and Syahrul Ridhwan Morazuk	46
PERFORMANCE OF MORTALITY RATES USING DEEP LEARNING APPROACH Mohamad Hasif Azim and Saiful Izzuan Hussain	53
UNSTEADY MHD CASSON FLUID FLOW IN A VERTICAL CYLINDER WITH POROSITY AND SLIP VELOCITY EFFECTS Wan Faezah Wan Azmi, Ahmad Qushairi Mohamad, Lim Yeou Jiann and Sharidan Shafie	60
DISJUNCTIVE PROGRAMMING - TABU SEARCH FOR JOB SHOP SCHEDULING PROBLEM S. Z. Nordin, K.L. Wong, H.S. Pheng, H. F. S. Saipol and N.A.A. Husain	68
FUZZY AHP AND ITS APPLICATION TO SUSTAINABLE ENERGY PLANNING DECISION PROBLEM <i>Liana Najib and Lazim Abdullah</i>	78
A CONSISTENCY TEST OF FUZZY ANALYTIC HIERARCHY PROCESS Liana Najib and Lazim Abdullah	89
FREE CONVECTION FLOW OF BRINKMAN TYPE FLUID THROUGH AN COSINE OSCILLATING PLATE	98

Siti Noramirah Ibrahim, Ahmad Qushairi Mohamad, Lim Yeou Jiann, Sharidan Shafie and Muhammad Najib Zakaria

RADIATION EFFECT ON MHD FERROFLUID FLOW WITH RAMPED WALL106TEMPERATURE AND ARBITRARY WALL SHEAR STRESS106

Nor Athirah Mohd Zin, Aaiza Gul, Siti Nur Alwani Salleh, Imran Ullah, Sharena Mohamad Isa, Lim Yeou Jiann and Sharidan Shafie

PART 2: STATISTICS

A REVIEW ON INDIVIDUAL RESERVING FOR NON-LIFE INSURANCE Kelly Chuah Khai Shin and Ang Siew Ling	117
STATISTICAL LEARNING OF AIR PASSENGER TRAFFIC AT THE MURTALA MUHAMMED INTERNATIONAL AIRPORT, NIGERIA <i>Christopher Godwin Udomboso and Gabriel Olugbenga Ojo</i>	123
ANALYSIS ON SMOKING CESSATION RATE AMONG PATIENTS IN HOSPITAL SULTAN ISMAIL, JOHOR Siti Mariam Norrulashikin, Ruzaini Zulhusni Puslan, Nur Arina Bazilah Kamisan and Siti Rohani Mohd Nor	137
EFFECT OF PARAMETERS ON THE COST OF MEMORY TYPE CHART Sakthiseswari Ganasan, You Huay Woon and Zainol Mustafa	146
EVALUATION OF PREDICTORS FOR THE DEVELOPMENT AND PROGRESSION OF DIABETIC RETINOPATHY AMONG DIABETES MELLITUS TYPE 2 PATIENTS <i>Syafawati Ab Saad, Maz Jamilah Masnan, Karniza Khalid and Safwati Ibrahim</i>	152
REGIONAL FREQUENCY ANALYSIS OF EXTREME PRECIPITATION IN PENINSULAR MALAYSIA <i>Iszuanie Syafidza Che Ilias, Wan Zawiah Wan Zin and Abdul Aziz Jemain</i>	160
EXPONENTIAL MODEL FOR SIMULATION DATA VIA MULTIPLE IMPUTATION IN THE PRESENT OF PARTLY INTERVAL-CENSORED DATA <i>Salman Umer and Faiz Elfaki</i>	173
THE FUTURE OF MALAYSIA'S AGRICULTURE SECTOR BY 2030 Thanusha Palmira Thangarajah and Suzilah Ismail	181
MODELLING MALAYSIAN GOLD PRICES USING BOX-JENKINS APPROACH Isnewati Ab Malek, Dewi Nur Farhani Radin Nor Azam, Dinie Syazwani Badrul Aidi and Nur Syafiqah Sharim	186
WATER DEMAND PREDICTION USING MACHINE LEARNING: A REVIEW Norashikin Nasaruddin, Shahida Farhan Zakaria, Afida Ahmad, Ahmad Zia Ul-Saufie and Norazian Mohamaed Noor	192
DETECTION OF DIFFERENTIAL ITEM FUNCTIONING FOR THE NINE- QUESTIONS DEPRESSION RATING SCALE FOR THAI NORTH DIALECT	201

Suttipong Kawilapat, Benchlak Maneeton, Narong Maneeton, Sukon Prasitwattanaseree, Thoranin Kongsuk, Suwanna Arunpongpaisal, Jintana Leejongpermpool, Supattra Sukhawaha and Patrinee Traisathit

ACCELERATED FAILURE TIME (AFT) MODEL FOR SIMULATION PARTLY 210 INTERVAL-CENSORED DATA

Ibrahim El Feky and Faiz Elfaki

MODELING OF INFLUENCE FACTORS PERCENTAGE OF GOVERNMENTS' RICE 217 RECIPIENT FAMILIES BASED ON THE BEST FOURIER SERIES ESTIMATOR 217

Chaerobby Fakhri Fauzaan Purwoko, Ayuning Dwis Cahyasari, Netha Aliffia and M. Fariz Fadillah Mardianto

CLUSTERING OF DISTRICTS AND CITIES IN INDONESIA BASED ON POVERTY 225 INDICATORS USING THE K-MEANS METHOD 225

Khoirun Niswatin, Christopher Andreas, Putri Fardha Asa OktaviaHans and M. Fariz Fadilah Mardianto

ANALYSIS OF THE EFFECT OF HOAX NEWS DEVELOPMENT IN INDONESIA 233 USING STRUCTURAL EQUATION MODELING-PARTIAL LEAST SQUARE

Christopher Andreas, Sakinah Priandi, Antonio Nikolas Manuel Bonar Simamora and M. Fariz Fadillah Mardianto

A COMPARATIVE STUDY OF MOVING AVERAGE AND ARIMA MODEL IN 241 FORECASTING GOLD PRICE

Arif Luqman Bin Khairil Annuar, Hang See Pheng, Siti Rohani Binti Mohd Nor and Thoo Ai Chin

CONFIDENCE INTERVAL ESTIMATION USING BOOTSTRAPPING METHODS 249 AND MAXIMUM LIKELIHOOD ESTIMATE

Siti Fairus Mokhtar, Zahayu Md Yusof and Hasimah Sapiri

DISTANCE-BASED FEATURE SELECTION FOR LOW-LEVEL DATA FUSION OF 256 SENSOR DATA

M. J. Masnan, N. I. Maha3, A. Y. M. Shakaf, A. Zakaria, N. A. Rahim and N. Subari

BANKRUPTCY MODEL OF UK PUBLIC SALES AND MAINTENANCE MOTOR 264 VEHICLES FIRMS

Asmahani Nayan, Amirah Hazwani Abd Rahim, Siti Shuhada Ishak, Mohd Rijal Ilias and Abd Razak Ahmad

INVESTIGATING THE EFFECT OF DIFFERENT SAMPLING METHODS ON 271 IMBALANCED DATASETS USING BANKRUPTCY PREDICTION MODEL

Amirah Hazwani Abdul Rahim, Nurazlina Abdul Rashid, Abd-Razak Ahmad and Norin Rahayu Shamsuddin

INVESTMENT IN MALAYSIA: FORECASTING STOCK MARKET USING TIME 278 SERIES ANALYSIS

Nuzlinda Abdul Rahman, Chen Yi Kit, Kevin Pang, Fauhatuz Zahroh Shaik Abdullah and Nur Sofiah Izani

PART 3: COMPUTER SCIENCE & INFORMATION TECHNOLOGY

ANALYSIS OF THE PASSENGERS' LOYALTY AND SATISFACTION OF AIRASIA 291 PASSENGERS USING CLASSIFICATION 291

Ee Jian Pei, Chong Pui Lin and Nabilah Filzah Mohd Radzuan

HARMONY SEARCH HYPER-HEURISTIC WITH DIFFERENT PITCH 299 ADJUSTMENT OPERATOR FOR SCHEDULING PROBLEMS

Khairul Anwar, Mohammed A.Awadallah and Mohammed Azmi Al-Betar

A 1D EYE TISSUE MODEL TO MIMIC RETINAL BLOOD PERFUSION DURING 307 RETINAL IMAGING PHOTOPLETHYSMOGRAPHY (IPPG) ASSESSMENT: A DIFFUSION APPROXIMATION – FINITE ELEMENT METHOD (FEM) APPROACH Harnani Hassan, Sukreen Hana Herman, Zulfakri Mohamad, Sijung Hu and Vincent M. Dwyer

INFORMATION SECURITY CULTURE: A QUALITATIVE APPROACH ON 325 MANAGEMENT SUPPORT

Qamarul Nazrin Harun, Mohamad Noorman Masrek, Muhamad Ismail Pahmi and Mohamad Mustaqim Junoh

APPLY MACHINE LEARNING TO PREDICT CARDIOVASCULAR RISK IN RURAL 335 CLINICS FROM MEXICO

Misael Zambrano-de la Torre, Maximiliano Guzmán-Fernández, Claudia Sifuentes-Gallardo, Hamurabi Gamboa-Rosales, Huizilopoztli Luna-García, Ernesto Sandoval-García, Ramiro Esquivel-Felix and Héctor Durán-Muñoz

ASSESSING THE RELATIONSHIP BETWEEN STUDENTS' LEARNING STYLES 343 AND MATHEMATICS CRITICAL THINKING ABILITY IN A 'CLUSTER SCHOOL' Salimah Ahmad, Asyura Abd Nassir, Nor Habibah Tarmuji, Khairul Firhan Yusob and Nor Azizah Yacob

STUDENTS' LEISURE WEEKEND ACTIVITIES DURING MOVEMENT CONTROL 351 ORDER: UiTM PAHANG SHARING EXPERIENCE

Syafiza Saila Samsudin, Noor Izyan Mohamad Adnan, Nik Muhammad Farhan Hakim Nik Badrul Alam, Siti Rosiah Mohamed and Nazihah Ismail

DYNAMICS SIMULATION APPROACH IN MODEL DEVELOPMENT OF UNSOLD 363 NEW RESIDENTIAL HOUSING IN JOHOR

Lok Lee Wen and Hasimah Sapiri

WORD PROBLEM SOLVING SKILLS AS DETERMINANT OF MATHEMATICS 371 PERFORMANCE FOR NON-MATH MAJOR STUDENTS 371

Shahida Farhan Zakaria, Norashikin Nasaruddin, Mas Aida Abd Rahim, Fazillah Bosli and Kor Liew Kee

ANALYSIS REVIEW ON CHALLENGES AND SOLUTIONS TO COMPUTER 378 PROGRAMMING TEACHING AND LEARNING

Noor Hasnita Abdul Talib and Jasmin Ilyani Ahmad

PART 4: OTHERS

ANALYSIS OF CLAIM RATIO, RISK-BASED CAPITAL AND VALUE-ADDED 387 INTELLECTUAL CAPITAL: A COMPARISON BETWEEN FAMILY AND GENERAL TAKAFUL OPERATORS IN MALAYSIA Nur Amalina Syafiga Kamaruddin, Norizarina Ishak, Siti Raihana Hamzah, Nurfadhlina Abdul Halim and Ahmad Fadhly Nurullah Rasade THE IMPACT OF GEOMAGNETIC STORMS ON THE OCCURRENCES OF 396 EARTHOUAKES FROM 1994 TO 2017 USING THE GENERALIZED LINEAR MIXED MODELS N. A. Mohamed, N. H. Ismail, N. S. Majid and N. Ahmad **BIBLIOMETRIC ANALYSIS ON BITCOIN 2015-2020** 405 Nurazlina Abdul Rashid, Fazillah Bosli, Amirah Hazwani Abdul Rahim, Kartini Kasim and Fathiyah Ahmad@Ahmad Jali GENDER DIFFERENCE IN EATING AND DIETARY HABITS AMONG UNIVERSITY 413 **STUDENTS** Fazillah Bosli, Siti Fairus Mokhtar, Noor Hafizah Zainal Aznam, Juaini Jamaludin and Wan Siti Esah Che Hussain MATHEMATICS ANXIETY: A BIBLIOMETRIX ANALYSIS 420 Kartini Kasim, Hamidah Muhd Irpan, Noorazilah Ibrahim, Nurazlina Abdul Rashid and Anis Mardiana Ahmad

PREDICTION OF BIOCHEMICAL OXYGEN DEMAND IN MEXICAN SURFACE 428 WATERS USING MACHINE LEARNING 428

Maximiliano Guzmán-Fernández, Misael Zambrano-de la Torre, Claudia Sifuentes-Gallardo, Oscar Cruz-Dominguez, Carlos Bautista-Capetillo, Juan Badillo-de Loera, Efrén González Ramírez and Héctor Durán-Muñoz

EFFECT OF PARAMETERS ON THE COST OF MEMORY TYPE CHART

Sakthiseswari Ganasan¹, You Huay Woon^{2*} and Zainol Mustafa³

^{1,3} Pusat Pengajian Sains Matematik, Fakulti Sains dan Teknologi, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

² Pusat GENIUS@Pintar Negara, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor,

Malaysia

(¹ sakthignsn@hotmail.com, ² hwyou@ukm.edu.my and ³ zbhm@ukm.edu.my)

*Corresponding author

A memory type control chart is a scheme that utilizes previous information for constructing the chart. An exponentially weighted moving average (EWMA) control chart is an example of a memory type chart. The EWMA control chart is well-known and widely employed by practitioners for monitoring small and moderate process mean shifts. In light of this, the cost of implementing an EWMA control chart needs to be determined. This study aims to investigate the effect of input parameters on the cost of implementing an EWMA control chart. Here, the economic model was used to compute the cost parameter. The 14 input parameters were identified and the analysis was carried out based on the one-parameter-at-a-time basis. When the input parameters change based on a predetermined percentage, the cost is also affected. According to the results, 10 input parameters with major effect and 4 input parameters with almost no effect on the cost parameter. However, the effect of each input parameter on the cost is different. This analysis is crucial to observe and determine the input parameters that have a significant impact on the cost of the EMWA control chart. Hence, practitioners can obtain an overview of the influence of the input parameters on the cost of implementing the EWMA control chart.

Keywords: Cost, Economic model, Sensitivity analysis

1. Introduction

Statistical Process Control (SPC) is a collection of analytical decision making tools that are effective to achieve process reliability and enhance capability by reducing variability. A control chart is among the most efficient tools in SPC (Montgomery, 2019). The first control chart was pioneered by Dr. Walter A. Shewhart to monitor and determine whether a process is in a desired state for producing high quality goods (Abtew et al., 2018).

Since then, the control chart remains a valuable tool in SPC. This is because it can continuously monitor a process and ultimately improve its capability. Meanwhile, it is simple to use, yet achieves a significant impact on the enhancement of quality (You et al., 2020). The awareness and knowledge of using control charting techniques to monitor a process and deliver high-quality production has grown exponentially (Şengöz, 2018). Hence, control charts are used extensively in the manufacturing and service sectors.

The Shewhart chart has been known for its ease of construction and implementation. Nevertheless, it is insensitive towards small and moderate process shifts. Consequently, extensive research has been conducted to develop new control charts to improve the sensitivity of the Shewhart chart, such as the memory type control chart (Abbas, 2018). A memory type control chart is constructed based on past and current information. Here, an example of the memory type control chart is the exponentially weighted moving average (EWMA) chart.

The assessment of a control chart is necessary to reveal its effectiveness. This is vital, as it influences the decision to use the control chart. In practice, the performance of a control chart can be evaluated (Chong et al., 2019). The common criteria to measure the performance of a control chart are average run length (ARL) and standard deviation of the run length (SDRL). Nonetheless, the expected cost to implement the control chart cannot be identified. The economic designs of the

memory type control chart have been studied by Hariba and Tukaram (2016) and Serel (2009), to name a few. The effect of input parameters on the implementation cost of the EWMA chart is not yet available in the literature.

In view of this, it is essential to investigate the impact of the input parameters on the expected cost of implementing the EWMA control chart. This work presents a brief description of the EWMA control chart. The economic model of the EWMA chart is also elaborated. Next, the sensitivity analysis of the EWMA control chart is conducted to identify the input parameters that influence the cost of the EWMA chart.

2. The EWMA Chart

The EWMA chart was developed by Roberts (1959), and is known as a memory type chart because it takes into account both previous and current data in establishing the control structure. In light of this, the EWMA chart is suitable to be used to detect small process mean shifts (Ramesh and Vasu, 2019).

The statistic of the EWMA chart at sampling period, *i*, is computed as follows:

$$z_i = \lambda x_i + (1 - \lambda) z_{i-1}, \tag{1}$$

where λ is a smoothing constant and $0 < \lambda \le 1$. When a z_i falls beyond the control limit, an outof-control situation is said to have occurred. Note that the EWMA chart is converted to a Shewhart chart when λ becomes 1 (Patel and Divecha, 2011).

3. The Economic Model of the EWMA Chart

The economic model of the EWMA chart, obtains optimal charting parameters that minimizes cost (Chung, 1991). Here, the economic model of the EWMA chart involves finding the expected cost of the EWMA chart. The implementing cost of the EWMA control chart is calculated based on the cost function.

When an assignable cause occurs, the process is said to become out-of-control, the process mean becomes $\mu_0 + \delta \sigma$. It is assumed that a process initiates in a state of in-control, and the time for an assignable cause to occur is exponentially distributed with mean $1/\theta$. The expected cost per hour is obtained from dividing the expected cost-per-cycle by the expected cycle length. The cycle is composed of an in-control phase, followed by an out-of-control phase.

The expected cost per unit time in hours is denoted as *C*, and can be defined as follows:

$$C = \frac{\frac{C_0}{\theta} + C_1 B + \frac{b + cn}{h} \left(\frac{1}{\theta} + B\right) + \frac{sY}{\text{ARL}_0} + W}{\frac{1}{\theta} + \frac{(1 - \varphi_1)sT_0}{\text{ARL}_0} + EH},$$
(2)

where

$$B = (ARL_1 - 0.5)h + F,$$

$$F = ne + \gamma_1 T_1 + \gamma_2 T_2,$$

$$s = \frac{1}{\lambda h} - 0.5,$$

$$EH = (ARL_1 - 0.5)h + G,$$

and

 $G = ne + T_1 + T_2$.

The notations in (2) are defined as follows:

- C_0 Expected quality cost per unit time, while the process is in-control
- C_1 Expected quality cost per unit time, while the process is out-of-control
- θ Process failure rate
- *b* Fixed cost per sample
- c Cost per unit sampled
- *n* Sample size
- *e* Expected time to sample and interpret one unit
- *h* Sampling interval
- *s* Expected number of samples taken before an assignable cause occurs
- *Y* Cost of false alarm
- ARL₀ Average run length when the process is in-control
- ARL₁ Average run length when the process is out-of-control
- *W* Cost of finding and fixing an assignable cause
- γ_1 = 1 if production continues during search
- = 0 if production stops during search
- γ_2 = 1 if production continues during repair
- = 0 if production stops during repair
- T_0 Expected time to search for a false alarm
- T_1 Expected time to find the assignable cause
- T_2 Expected time to repair the process

4. The Sensitivity Analysis of the EWMA Chart

Sensitivity analysis is crucial to identify the input parameter that has an impact on the cost of implementing the EWMA chart. Meanwhile, sensitivity analysis of input parameters of the EWMA control chart helps to determine the input parameters that are critical. Here, 14 input parameters $(\theta, \delta, C_0, C_1, Y, W, b, c, e, T_0, T_1, T_2, \gamma_1, \gamma_2)$ have been identified. Sensitivity analysis can be performed on a one factor at a time basis, where one of the input parameters is modified each time, while the other 13 input parameters remain unchanged. For example, the value for θ is 0.01, 0.02 and 0.04 each time, with the remainder of the input parameters remaining unchanged. In view of this, 40 different input parameter combinations $(\theta, \delta, C_0, C_1, Y, W, b, c, e, T_0, T_1, T_2, \gamma_1, \gamma_2)$ were taken

into account and are displayed in Table 1.

Table 2 demonstrates the corresponding cost values for the EWMA control chart. Here, the input parameters are $\theta = 0.02$, $\delta = 0.86$, $C_0 = 114.24$, $C_1 = 949.2$, Y = 977.4, W = 977.4, b = 0, c = 4.22, e = 0.083, $T_0 = 0.083$, $T_1 = 0.083$, $T_2 = 0.75$, $\gamma_1 = 1$, $\gamma_2 = 0$ and the corresponding optimal cost for the EWMA chart is 222.37. According to Table 2, the implementation cost of the EWMA control chart increases when the expected quality cost per unit time while the process is in-control, C_0 , increased, and vice versa. For instance, an increase of C_0 from 114.24 to 228.48 as in number 9 in Table 1 results in an increase in the expected cost from 222.37 to 327.97. The same situation occurs to the expected quality cost per unit time while the process is out-of-control, C_1 , and cost per unit sampled, c. Nevertheless, C_0 has a greater effect on expected cost than C_1 . This can be seen when C_0 increased, expected cost increased by 47.5%, while when C_1 increased, the expected cost. It can be noticed that the increase in the value of Y and W increased the expected cost by 3% and 8.1%, respectively. When fixed cost per sample, b, increased to 5 and 10, it was found that the expected cost for both cases increased by 7.1% and 12.4%, respectively.

According to Table 2, the expected cost remains the same, regardless of the increase or decrease of the input parameter expected time to search a false alarm, T_0 . Nonetheless, the expected time to sample and interpret one unit, e, and the expected time to determine the assignable cause, T_1 , have a

small impact on the expected cost. It was observed that when the *e* and T_1 increase to 0.166, the expected cost increases by 1.0% and 0.5%, respectively. In contrast, the expected cost decreases by 1.4% when the expected time to repair the process, T_2 , increases from 0.75 to 1.50. The process failure rate, θ , can be seen to have a significant effect on the optimal cost. This can be observed when θ decreased by 50% (i.e. from 0.02 to 0.01), the cost decreases from 222.37 to 187.91. However, when θ rises to 0.04, the cost rises to 273.66. The increase in cost occurs due to an increase in the process failure rate.

When the process shift, δ , increases by 50% from 0.86 to 1.72, the cost is reduced by 16.6%. As the size of process shift decreases, the cost increased by 25.3% from 222.37 to 278.56. A large process shift is easier to be detected than small process shift, hence, the cost is lower in the large process shift compared to the small process shift. The production status during search, γ_1 , and production status during repair, γ_2 , show that when production stops during search and repair, the optimal cost decreased from 222.37 to 220.67. The optimal cost increases by 6.1% when the production continues during search and repair. The same phenomenon occurs when the production stops during search and production continues during repair, i.e. increased by 5.4%. As discussed, 13 out of 14 input parameters have an effect on the output parameter, i.e. cost. However, the size of the effect of each input parameter on the cost is different.

No.	θ	δ	$C_0(\$)$	$C_1(\$)$	Y(\$)	W(\$)	<i>b</i> (\$)	<i>c</i> (\$)	е	T_0	T_1	T_2	γ 1	<i>Y</i> 2
1	0.01	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
2	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
3	0.04	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
4	0.02	0.43	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
5	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
6	0.02	1.72	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
7	0.02	0.86	57.12	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
8	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
9	0.02	0.86	228.48	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
10	0.02	0.86	114.24	474.6	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
11	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
12	0.02	0.86	114.24	1898.4	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
13	0.02	0.86	114.24	949.2	488.7	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
14	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
15	0.02	0.86	114.24	949.2	1954.8	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
16	0.02	0.86	114.24	949.2	977.4	488.7	0	4.22	0.083	0.083	0.083	0.75	1	0
17	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
18	0.02	0.86	114.24	949.2	977.4	1954.8	0	4.22	0.083	0.083	0.083	0.75	1	0
19	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
20	0.02	0.86	114.24	949.2	977.4	977.4	5	4.22	0.083	0.083	0.083	0.75	1	0
21	0.02	0.86	114.24	949.2	977.4	977.4	10	4.22	0.083	0.083	0.083	0.75	1	0
22	0.02	0.86	114.24	949.2	977.4	977.4	0	2.11	0.083	0.083	0.083	0.75	1	0
23	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
24	0.02	0.86	114.24	949.2	977.4	977.4	0	8.44	0.083	0.083	0.083	0.75	1	0
25	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.0415	0.083	0.083	0.75	1	0
26	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
27	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.166	0.083	0.083	0.75	1	0
28	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.0415	0.083	0.75	1	0
29	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
30	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.166	0.083	0.75	1	0
31	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.0415	0.75	1	0
32	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
33	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.166	0.75	1	0
34	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.375	1	0
35	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
36	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	1.50	1	0
37	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	0	0
38	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	0
39	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	0	1
40	0.02	0.86	114.24	949.2	977.4	977.4	0	4.22	0.083	0.083	0.083	0.75	1	1

Table 1: Different combinations of the input parameters.

No.	Cost	Percentage difference from optimal cost, %
1	187.91	-15.5
2	222.37	0.0
3	273.66	23.1
4	278.56	25.3
5	222.37	0.0
6	185.48	-16.6
7	194.60	-12.5
8	222.37	0.0
9	327.97	47.5
10	188.49	-15.2
11	222.37	0.0
12	269.11	21.0
13	215.28	-3.2
14	222.37	0.0
15	229.03	3.0
16	213.31	-4.1
17	222.37	0.0
18	240.47	8.1
19	222.37	0.0
20	238.22	7.1
21	250.04	12.4
22	202.44	-9.0
23	222.37	0.0
24	246.67	10.9
25	221.20	-0.5
26	222.37	0.0
27	224.69	1.0
28	222.37	0.0
29	222.37	0.0
30	222.37	0.0
31	221.78	-0.3
32	222.37	0.0
33	223.53	0.5
34	223.92	0.7
35	222.37	0.0
36	219.32	-1.4
37	220.67	-0.8
38	222.37	0.0
39	234.29	5.4
40	236.00	61

Table 2: Optimal cost of the EWMA control chart.

5. Conclusion

The EWMA control chart has been known for its quick detection of small and moderate process mean shifts. In this study, sensitivity analysis was conducted to determine the effect of the input parameters on the cost of implementing the EWMA control chart. The sensitivity analysis was carried out by increasing and decreasing the values of the input parameters by 50%. All input parameters, namely, θ , δ , C_0 , C_1 , Y, W, b, c, e, T_0 , T_1 , T_2 , γ_1 and γ_2 were subjected to sensitivity analysis. The findings of the study indicate that such a variation affects the implementation cost of the EWMA control chart. The input parameters that have a major effect on the cost are θ , δ , C_0 , C_1 , Y, W, b, c, γ_1 and γ_2 . The expected quality cost per unit time while the process is in-control, C_0 , has the most impact on the cost when C_0 is increased by 50%. The cost of implementing the EWMA control chart is increased by 47.5% when C_0 is increased by 50%. In contrast, input parameters e, T_0 , T_1 and T_2 have almost no effect on the implementation cost of the EWMA control chart. As this study is based on the sensitivity analysis of the EWMA control chart, future research work can be extended by comparing the effect of the input parameters on the implementation cost for several control charts.

Acknowledgment

This research is supported by the Universiti Kebangsaan Malaysia, Geran Galakan Penyelidikan, GGP-2020-040.

References

- Abbas, N. (2018). Homogeneously weighted moving average control chart with an application in substrate manufacturing process. *Computers & Industrial Engineering*, 120:460-470.
- Abtew, M. A., Kropi, S., Hong, Y., and PU, L. (2018). Implementation of statistical process control (SPC) in the sewing section of garment industry for quality improvement. *AUTEX Research Journal*, 18:160-172.
- Chong, Z. L., Khoo, M. B. C., Teoh, W. L., You, H. W., and Castagliola, P. (2019). Optimal design of the side-sensitive modified group runs (SSMGR) \overline{X} chart when process parameters are estimated. *Quality and Reliability Engineering International*, 35:246-262.
- Chung, K. J. (1991). A simplified procedure for the economic design of control charts: a unified approach. *Journal Engineering Optimization*, 4:313-320.
- Hariba, P. S. and Tukaram, S. D. (2016). Economic design of a nonparametric EWMA control chart for location. *Production*, 26:698-706.
- Montgomery, D. C. (2019). Introduction to statistical quality control. 8th ed. New York: John Wiley & Sons, Inc.
- Patel, A. K., and Divecha, J. (2011). Modified exponentially weighted moving average (EWMA) control chart for an analytical process data. *Journal of Chemical Engineering and Materials Science*, 2:12-20.
- Ramesh, S., and Vasu, B. A. (2019). Application of EWMA chart for monitoring process mean in paper industry. *Management Science Letter*, 9:571-576.
- Roberts, S. W. (1959). Control chart tests based on geometric moving averages. *Technometrics*, 1:239-250.
- Şengöz, N. G. (2018). Control charts to enhance quality. *Quality Management Systems A Selective Presentation of Case-Studies Showcasing Its Evolution*, 153-194.
- Serel, D. A. (2009). Economic design of EWMA control charts based on loss function. *Mathematical and Computer Modelling*, 49:745-759.
- You, H. W., Khoo, M. B. C., Chong, Z. L., and Teoh, W. L. (2020). The expected average run length of the EWMA median chart with estimated process parameters. *Austrian Journal of Statistics*, 49:19-24.





