Ergonomic Design of Computer Workstations of High School Students Studying at Home

Ryan Gabriel D. Cadiz and Castro James J. Guerrero
Young Innovators Research Center
Mapúa University
Intramuros, Manila 1002, Philippines
rgdcadiz@mymail.mapua.edu.ph, cjjguerrero@mymail.mapua.edu.ph

Ma. Janice J. Gumasing
School of Industrial Engineering and Engineering Management
Mapúa University
Manila, Philippines
mjjgumasing@mapua.edu.ph

Abstract

High school students, especially in the time of pandemic, have online classes, which requires the students to expose themselves to computer workstations, putting them at risk of developing musculoskeletal disorders. This study aims to assess and evaluate the current setup used by the students studying at home. The main objective of this study is to design an ergonomic workstation for high school students who are studying at home. The data that were gathered from the respondents (n=100) include discomfort level using Corlett's and Bishop's body map questionnaire, risk level of sitting posture using Rapid Upper Limb Assessment (RULA) and anthropometric dimensions as such as popliteal height, sitting elbow height, buttock-popliteal depth, hip breath, sitting shoulder height and range of functional reach. The data that were gathered from the respondents were statistically treated and analyzed using ANOVA for mean comparison and correlation analysis. There were several factors that were considered in the study to determine the cause of body discomfort of students while using the current computer workstation in their homes while studying online. The factors include duration of study, area of study, chair design and table design. The study found out that the duration of study and the type of chair have a significant difference with the discomfort scores of students, meaning these factors significantly affect the discomfort level of the students while studying at home. Another finding is that the RULA score ($r=0.854$, p-value<0.001) and the table height dimension ($r=0.773$, p-value<0.001) have a positive relationship with the discomfort scores while seat height ($r=-0.693$, p-value<0.001) has negative relationship with discomfort scores of students. The study concluded that some dimensions and the duration of exposure to computer workstations puts high school students at higher risk of developing musculoskeletal disorders. Given these conditions, we have proposed an ergonomic workstation deign for students based on their gathered anthropometric measurements.

Keywords
Ergonomics, Computer Workstation, Musculoskeletal Disorders, Anthropometry.

1. Introduction
Work is defined as the dedication of mental and physical capabilities to accomplish a task (Merriam-Webster Dictionary, 2020). Based on the definition, the classification of academics falls under it. Educational institutions demand from students a huge investment of time, effort, and cognitive ability such as learning, remembering, problem-solving, and attention (SharpBrains, 2020), with the duration of an average Philippine class being 6 and a half hours long worth of lessons, seatworks, and quizzes (State University, 2020). Since the year 2020, digitally speaking, is included in a generation called Generation Alpha, the people that currently live in such an era are preoccupied with the technology that is thriving (Pinsker, 2020). Consequently, the usage of computers would be frequent, as the National Center for Education Statistics (1999) presented 88% of computer-available teachers reporting the usage of computers in school facilities and the use of computers as a means of curricular instruction that may or may not also require the use of computers for the students' end. Due to technological evolution from 1999-2020 and the Department

of Education launching online classes on the 24th of August in the Philippines (Briones, 2020), the frequency of usage and demand for a computer is high especially due to the pandemic (Santos, 2020). Even with the integration of technology and learning, physical health still directly affects productivity and participation, as higher academic performances resulted from proper sleep and sustenance from students (Burns, 2018). The paper by Aston (2018) determined that a healthy school environment is effective, with the inclusion of educational intervention, in the improvement of the quality of life of a student. Since posture is considered to be vital in the physical health of a person in the long run (Physiopedia, 2020) and the close relationship between posture and ergonomics (Clarke, 2012) yet the minimal knowledge of ergonomics between students as a prevention of the risk of bodily aches (Sirajudeen, 2017), ergonomic (particularly anthropometric) adjustments to workstation design is deemed necessary in order to maintain such aspect of physical health.

The bulk of related studies have similar results when ergonomic interventions are applied to workstation designs with different data collection methods and means of analysis, and the result is that dimensional adjustments of the workplace is important to improve the quality of life for everyone who is subject to everyday work, and that there is no one-size-fits-all solution for the construction of workplace furniture. (Abbas et al., 2019; Robertson et al., 2013; Oyewole et al., 2010; Dockrell et al., 2010; Punchihewa et al., 2015; van Niekerk et al., 2013; Gumasing & Espejo, 2020; Gumasing, Abalajon, Espejo, 2020; Gumasing, Aruego, Segovia, 2020)

While existing studies have clearly established such, they have not fully explored the area of online classes due to the deficiency of its existence in times before the current pandemic, nor have high school students been participants of the study on ergonomic intervention. Studies related have dimensional adjustments in the working or learning environment, with the sample population being primary school students or the actual working class (nurses, computer operators, and office workers), with little focus to the design of the design of computer workstation and more attention to the furniture of the on-site locations.

1.1 Objectives

The present research, with all things considered, firstly aims to assess and evaluate the current setup used by students studying at home. This allows for data collection in the study as well as analyze problems that may be found after thorough investigation. The next aim is to evaluate the comfortability of students in using the current set-up and identify factors affecting such level. This ensures ease if the study is successful in designing the computer workstation and urgency for the research to be pursued if the levels are lower than average. The final goal is to design an ergonomic workstation for students studying at home. This allows ergonomic suggestions to happen and achieve any target goal that concerns on the improvement of the quality of life.

2. Literature Review

Levanon et al. (2012) aimed to examine the efficacy level of a workplace design mediation for computer operators that were informed and was presented to them ahead of time and analyze whether or not ergonomic changes to their work environment would relieve MSDs and promote better body positioning to the target audience. The study was done through the assessment of MSDs by means of gathering demographic data that specifically included age, education, and biometrics to 66 participants who complained about musculoskeletal-related problems and excluding the workers who had orthopedic (such as pregnancies or arthritis) and mental related issues. Rapid upper limb assessments (RULA) and The Standard Nordic Questionnaire (SNQ) were both administered before and after the mediation to be the basis of data analysis using Kolmogorov-Smirnov for examination of variables that are normally distributed, One-way Analysis of Variance (ANOVA) due to the data's normality, and Kruskal-Wallis for homogeneity. Worksite adjustments to anthropometrics, muscle exercises, and breaks during work hours with ergonomic interventions by biofeedback programme effectively reduced computer-related MSD score among participants, yielding the result that the ergonomic modifications effectively relieved MSDs and promoted better body positions for the computer operators.

A descriptive study conducted by van Niekerk et al. (2012) aimed to evaluate anthropometric dimensions of computer workstation in schools found in Africa, specifically in four centers of education that covers most of Cape Town (Cape Metropole, Western Cape, and South Africa). The study included 689 students who were sampled by cluster in these four districts, where the inclusions were the participants should be 13-18 years of age, in the 8th to 12th grade, and were enrolled in the school selected for participation. There were no specific exclusions that were added for the study, as long as the qualifications were met, any student could participate in the study. The participants were subject to measurement, with their posture, popliteal height, buttock-to-popliteal length and hip width being examined through the use of a standard measuring tape, a T-square for body height, while a standard weighing scale for the weight. These were then compared with the dimensions of the same students sitting on the chair with their thighs fully occupying the seat, an upright trunk, and a 90-degree posture with their knees. The data sets gathered were analyzed through descriptive statistics in SPSS and were separated by age groups. The study found that 89% of the students did not match the dimensions of the seat and were identified to be too big for the depth of the chair, but 65% matched the width of the chair. The study formulated a conclusion that schools in Africa failed to follow the standard ergonomic recommendations to fit the user and supports the idea of not having a one-size-fits-all solution.

3. Methods

3.1. Survey Administration

The researchers individually reached out to students that qualify the scope of the study. After giving an ample amount of time, the data gathered was converted into spreadsheet form and was sorted and filtered for an easier analysis. The target subject was set by the researchers and the first step towards the collection of the data was through the selection of the participants through the usage of convenience non-random sampling due to the restrictions of the current situation. The next step was that a survey was administered, comprising three important sections that have their own function and role in the achievement of the objectives of the study. The survey's first section was dedicated to the information of the respondents of what the study is about, the apparatuses needed, and reminders and remarks from the researchers in taking the survey. The answer required was a single option, stating that the respondents agree to the terms and conditions of taking the survey and consent to use their information for the data of the study. The demographics section of the survey was carefully designed to evaluate the current setups for students studying at home as well as the bulk of the collection of the data needed for the study to continue. A part of the survey as well was the Corlett & Bishop's Discomfort Questionnaire. Created by Corlett and Bishop (1976), the questionnaire is designed for the evaluation of the comfortability level through the Likert Scale, with 1 being "Extremely Comfortable" all the way up to 5 being "Extremely Uncomfortable" in the students' usage of their setups. The utilization of such could also determine a problem in the dimensions of the design of their respective computer workstation.

3.2. Data Analysis

The data was sorted and subjected into different statistical tests to find any differences, relationships, and underlying results that could be drawn from the behavior of the data. The Rapid Upper Limb Assessment (RULA) was firstly used in the analysis. Created by McAtamney and Corlett (1993), the pictures provided by the respondents were estimated and measured based on their exposure to the computer workstation setup used. The results of these were subjected to the RULA which had its own scoring system of the discomfort level of people using a computer workstation setup. The scores per body part were averaged. Each demographic was then presented through a pie chart to show the frequency rate of the sample as well as to present the data in a clearer and visually-easier manner. Created by Bernard Lewis Welch (1947), the Welch's t-test was utilized if the means compared were from two groups. The statistical test was used rather than the Student's t-test due to the fact that the researchers assumed unequal variances between the data groups. The result determines whether or not a significant difference is found between the two groups. Created by Ronald Fisher (1918), the Analysis of Variance (ANOVA) statistical test was utilized if the means compared were from three or more groups. The result determines whether or not a significant difference is found among the groups. An interval plot was created to visually present the difference among the groups, with no overlapping lines from each category meaning that a significant difference is found between Group A and Group B. The group then used the Correlation analysis. Created by Francis Galton's (1888), the statistical test was used to determine any underlying relationships between groups, with a positive r-value meaning a strong relationship that which gets stronger the closer of the r-value is to 1, while a negative r-value identifies that a weak relationship exists that gets weaker the closer of the r-value is to -1. In addition, the averages of the anthropometric measurements were then calculated and separated into two categories: male population and female population. The mean was then used to calculate for the 5th and 95th percentiles to account for outliers in the population. The dimensions recommended were drawn from the anthropometric measurements which had a corresponding dimension of the chair and table, ultimately creating a chair and a table that would optimally give comfort to anyone who uses such a setup. The recommended dimensions were then compared to the dimensions found in the data gathered each according to the chair type and table type, describing the maximum and minimum dimension for each. The analysis determines if a recommended dimension is within the range of the maximum and minimum measurement per chair and table type. After the analysis the researchers searched for the chair and table dimensions that are the closest to the recommended measurement.

3.3. Computer Workstation Design and Development

Finally, with the new information presented and conclusions drawn from the behavior of the data set, the researchers designed, developed, and recommended a relatively optimal setup of the computer workstations for students studying and having classes in the comfort of their own home based on the data given. This was done through SketchUp, a 3D design software that allows for the architectural designs. The researchers focused on a simple design of what the most optimal setup would look like with the recommended dimensions.

4. Results and Discussion

4.1. Result of Discomfort Scores

From Figure 1, it could be seen that the highest score of discomfort is 3.61, located around the lower back or located around the pelvic area, while the lowest score of discomfort is 2.67, located from the feet/ankle. The mean of the discomfort score is 2.69.

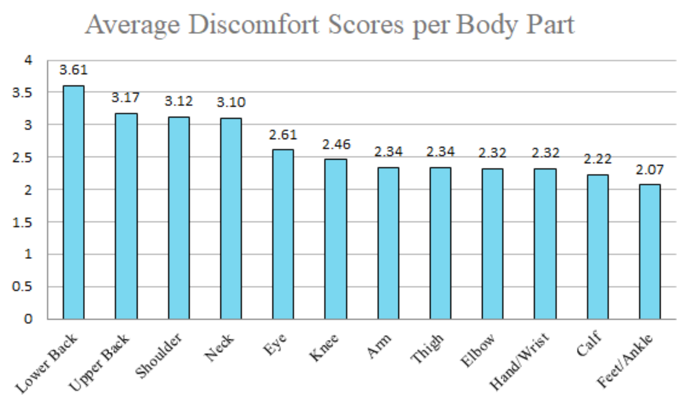

Figure 1. Discomfort Scores Arranged from Descending Order

4.2. Result of Statistical Analysis

Table 1. Summary of ANOVA Result

Factors	Variable	Mean	Std. Dev.	p-value	Remarks
Age	14-71 y/o	33.6	10.6	0.553	Not significant
	18-21 y/o	31.43	9.25		
Gender	Male	31.2	10.8	0.658	Not significant
	Female	32.53	8.30		
Area of study	Bedroom	30.24	9.50	0.115	Not significant
	Study area	34.33	7.34		
	Living room	40.00	7.30		
Duration of study	3-6 hrs	30.27	5.85	0.000	Significant
	6-9 hrs	31.06	7.83		
	10-12 hrs	44.75	9.07		
	12-14 hrs	45.50	7.33		
Chair type	Stool	41.33	5.65	0.000	Significant
	Monobloc	34.43	8.80		
	Wooden	35.25	6.09		
	Office	25.35	5.94		
Table type	Glass	29.67	8.62	0.607	Significant
	Plastic	26.67	8.50		
	Wooden	32.29	7.46		

Ho: all means are equal
Ha: at least one mean is different

The result of the t-test showed that there is no significant difference between the discomfort scores of respondents aged 14-17 years old and 18-21 years, having a p-value > 0.05, meaning that age does not determine the increase or decrease of the level of discomfort in using the computer workstation setup. Similarly, the result of the t-test showed that there is no significant difference between the discomfort scores of male and female respondents, having a p-value > 0.05, meaning that the biological sex of a person does not affect the discomfort level in using the computer workstation setup. The area of study and table type also showed no significant difference in discomfort level of students having p-value > 0.05. This means that the area of study such as bedroom, living room, dining room and others does not have affect the discomfort level of students while they are studying as well as their type of table used such as plastic, wooden, metal and glass.

On the other hand, the result of one-way ANOVA in Table 1 showed that there is a significant difference in the discomfort scores of respondents based on chair type used, having a p-value < 0.05. The result of the interval plot had proved that students using office chairs had significantly lower discomfort scores than students using stool, monobloc and wooden chairs, meaning that sitting on any other type of chair while studying decreases the comfort level. Office/gaming chairs have cushions on the back and the butt as well as arm support, reducing the force exerted and the stress applied to the body. Monobloc chairs nearly overlapped the interval plot for office/gaming chairs because it is made of plastic which is more tensile. This means that it could be molded and therefore add more lumbar support to the body, unlike a wooden chair that is rigid and more linear which would not really support the body. Stools may have butt cushions, but the fact that the back could not rest, adds to the discomfort level of a person since a greater force is exerted and a greater stress is applied.

Similarly, the result of one-way ANOVA showed that there is a significant difference in the discomfort scores of respondents based on duration of study, having a p-value < 0.05. The result of the interval plot had proved that students studying between 10-12 hrs and 12-14 hrs have significantly higher discomfort scores than students studying between 3-6 hrs and 6-9 hrs. As the interval plot suggests, discomfort levels exist from 3-9 hours of exposure to the computer workstation setup, but as it reaches the 10th -hour mark, a much higher discomfort level would be experienced that is bound to increase the longer the exposure continues. The data backs up the fact that musculoskeletal diseases are usually contracted from the time and exposure of the person in using a certain setup.

4.3. Result of Correlation Analysis

The result of correlation analysis in Table 2 showed that factors that have a significant relationship to the discomfort scores of students are sitting posture, seat height and table height, having p-value <0.05. Since the Pearson correlation value of seat height is - 0.693, it proves that the relationship between this factor to the discomfort score is negatively correlated. In other words, as the height of the seat increases, the discomfort score of respondents decreases. We can infer from this analysis that the students experience body discomfort because the current design of seat height is too high for the users. On the other hand, since the Pearson correlation value of sitting posture and table height is 0.854 and 0.773 respectively, it proves that the relationship of these factors to the discomfort score is positively correlated. In other words, as the risk of sitting posture increases as well as the height of the table increases, the discomfort scores of students also increase. An inference can be made from this analysis, that seating position and table height directly affects comfort level.

Table 2. Result of Correlation Analysis

Factors	Pearson correlation (r)	p-value	Remarks
Age	0.027	0.854	Not significant
Sitting posture score	0.854	0.000	Significant
Seat height	-0.693	0.000	Significant
Seat depth	0.067	0.324	Not significant
Seat width	0.103	0.523	Not significant
Backrest height	-0.079	0.634	Not significant
Table height	0.773	0.000	Significant
Table depth	-0.194	0.223	Not significant
Table width	-0.277	0.079	Not significant

Ho: correlation coefficient is not significantly different from 0.
Ha: correlation coefficient is significantly different from 0.

4.4. Result of Anthropometric Measurements

Based on the summary of anthropometric measurements gathered from the respondents, the researchers were able to compute for the 5th % percentile (minimum), 50th % (average) and 95th % (maximum) to determine the recommended dimensions for workstation design as shown in Table 3.

Table 3. Summary of Anthropometric Measurement

Dimensions (cm)	MALE POPULATION (n=50)					FEMALE POPULATION (n=50)				
	Mean	Std. Dev.	5th% (min)	50th% (ave)	95th% (max)	Mean	Std. Dev.	5th% (min)	50th% (ave)	95th% (max)
Popliteal Height	43.33	2.57	39.1	43.33	47.56	40.34	2.9	35.57	40.34	45.11
Buttock-popliteal depth	46.4	3.72	40.28	46.4	52.52	45.14	3.69	39.07	45.14	51.21
Hip breadth	35.6	4.19	28.71	35.6	42.49	36.39	4.83	28.44	36.39	44.34
Elbow to elbow breadth	30.57	2.07	27.16	30.57	33.98	28.85	1.68	26.09	28.85	31.61
Shoulder breadth	44.67	7.33	32.61	44.67	56.73	40.24	8.29	26.6	40.24	53.88
Sitting Shoulder Height	47.72	4.07	41.02	47.72	54.42	41.73	3.8	35.48	41.73	47.98
Sitting elbow height	22.23	4.21	15.3	22.23	29.16	21.89	4.09	15.16	21.89	28.62

The researchers used the measurements in reference to its anthropometric counterparts as shown in Table 4, the most optimal percentile, and the most optimal gender measurement to consider creating a design for the chairs and tables of the workplace. For example, if the design of interest is the seat height, the popliteal height of the data gathered. The percentile has three (3) categories: the minimum (5%), average (50%), and maximum (95%). The minimum percentile is people who are below the average anthropometric measurement, while the maximum percentile is the opposite. The percentiles and gender recommended would satisfy the majority who uses the chair or table dimensions.

Table 4. Recommended Dimensions for Ergonomic Design of Workstation

ERGONOMIC DESIGN OF WORKSTATION				
Dimension	Body Reference	Percentile	Gender	Recommended Dimension (cm)
Seat Height	Popliteal height	5th	Female	36
Seat Depth	Buttock popliteal depth	5th	Female	39
Seat Width	Hip breadth	95th	Female	44
Backrest Height	Sitting shoulder height	5th	Female	35
Table Height	Seat Height sitting elbow height	5th	Female	51
Table Depth	Functional forward reach	5th	Female	58
Table Width	Functional forward reach + shoulder breadth + functional forward reach	5th	Female	143

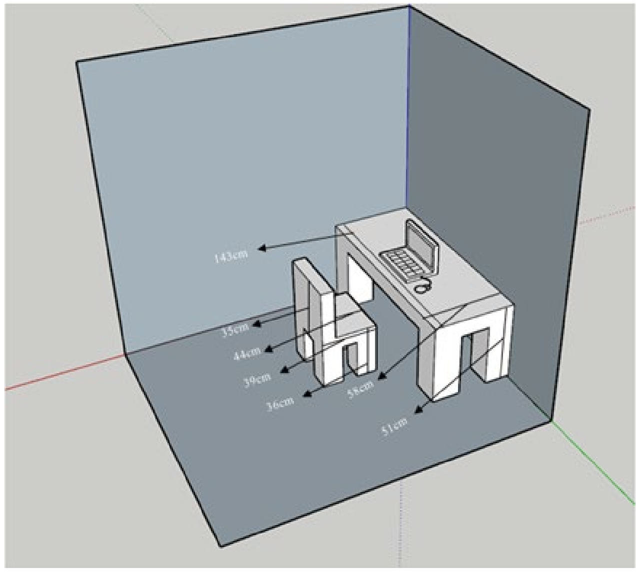

Figure 2. Recommended Design of the Computer Workstation

The image in Figure 2 presents a prototype design of the recommended computer workstation for the most optimal comfort level that satisfies the sample. The labels are the recommended dimensions per aspect of measurement of the chair and table. The recommended design is the most optimal design for comfort, meaning that following the suggestion decreases the risk of the contraction of musculoskeletal disorders for high school students using computer workstation setups.

6. Conclusion

The first objective of the study aimed to assess and evaluate the current setup used by students studying at home. The evaluation of the survey administered included pertinent information that would not only aid in the proceeding of the data analysis part of the research, but would also meet such objective. Further achievement was done with the used of the Rapid Upper Limb Assessment (RULA) that investigated the posture of each respondent that translated to a scoring system presenting the risk of each student in contracting musculoskeletal diseases (MSDs) in each part of the body. The findings present that the respondents' most frequent responses for each category are male, 18 years old, 6-9 hours, bedroom, morning-evening, office/gaming chair, and a wooden table. The researchers concluded that the most frequent responses present a general idea of the computer workstation setup and the behavior using such. The second objective aimed to evaluate the comfortability of students in using the current set-up and identify factors affecting such level. The first part of the objective was achieved with the usage of the Corlett's Bishop Discomfort Questionnaire which has a similar purpose with the goal targeted. The second part of the objective, on the other hand, was achieved with, first, the Welch's t-test that analyzed the difference between the demographics and the discomfort scores, and second, the correlation analysis that presented the relationship between the discomfort scores of the respondents and the demographics and factors gathered from the survey. The data that had a positive relationship were determined as factors that affected the discomfort level of the students, namely the duration of study and sitting posture while table height has negative relationship to the discomfort scores. The data also found out that there is a significant difference between the duration of study hours and the chair type with the discomfort scores. The researchers concluded that the duration of exposure, the amount of cushion, and the specific dimensions in a chair and a table affects the comfortability level of students. The final objective was designing an ergonomic workstation for students studying at home. The objective was obtained with the rough design of the computer workstation using the three-dimensional design software SketchUp wherein the dimensions in the design was in reference to the recommended dimensions of a chair and a table with the most optimal comfort for the high school students. The data found out that the recommended dimensions are within range for office/gaming, monobloc, and wooden chairs, but the wooden table is the only type of table that is within range. The researchers further conclude that there is a need for an ergonomic adjustment for the computer workstation dimensions to obtain the most optimal comfort for students.

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Biography

Ryan Gabriel D. Cadiz, at the time of the creation of the paper, is a senior high school Grade 12 student in Mapúa University and is the leader of the group. He has been trained in the writing of research papers in his education and has spearheaded every paper he is involved in and has also been awarded in his school "best presenter" in his research defenses. He continues to strive to create meaningful research papers that would fill the gap of knowledge in any field of interest. He plans to take a Bachelor of Science in Electrical Engineering. His research interests include automation, electromagnetism, ergonomics, and robotics.

Castro James J. Guerrero is a senior high school Grade 12 student at Mapua University and one of the members of the group. He has had countless awards and excellence, one of which is being the "Scientist of the Year" Award for presenting marvelous experiments. By having an integral role in the Design team on Creotec Immersion being the team's leader, he gained a comprehensive overview of team-building systems and their interaction. He aspires to receive a bachelor's degree in Civil Engineering here at Mapua University. His research interests include computer engineering, aerospace design, civil engineering, and aviation systems.

Assoc. Prof. Ma. Janice J. Gumasing is a Professor of School of Industrial Engineering and Engineering Management at Mapua University. She has earned her B.S. degree in Industrial Engineering and Masters of Engineering degree from Mapua University. She is a Professional Industrial Engineer (PIE) with over 15 years of experience. She is also a professional consultant of Kaizen Management Systems, Inc. She has taught courses in Ergonomics and Human Factors, Cognitive Engineering, Methods Engineering, Occupational Safety and Health and Lean Manufacturing. She has numerous international research publications in Human Factors and Ergonomics. She has been awarded as Woman in the Academia (WIA) 2019 during International Conference of Industrial Engineering and Operations Management held in Bangkok, Thailand, Young Researcher Award in 2020 International Conference of Industrial Engineering and Operations Management held in Dubai, UAE and Outstanding Conference Contributor Award in 2021 International Conference of Industrial Engineering and Operations Management in Singapore.