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Potential Carbon Dioxide Reduction From Optimal Task Performance Zone In An Office Space

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Abstract:
A post-occupancy evaluation (POE) was carried out on the identified optimum task performance zone (OTPZ) in an office space (Dodo 2015). The OTPZ is a zone that daylighting can be used most times except when the sky conditions are not favourable to provide up to 300lux. The amount of carbon dioxide (CO_2) saving when no artificial light is used this zone was calculated and tabulated. This can directly reduce building cooling energy usage The findings denotes that the OTPZ of 3m x 1m required lumens is 969 lm and 2 bulbs would be required to produce the desired power which will give a required illumination of about 323 lux. The study identified that OPTZ would reduce the amount of energy required to lit of the space and since the zone requires little or no artificial lighting, the amount of CO_2 emission will reduce. The result shows that about 304.82Kg of CO_2 will be saved from polluting the atmosphere if an Incandescent (60 Watts) lighting technology (800 Lumens) on a daily kilowatt bases is used. An equivalent of 69.86kg of CO_2 would be saved from polluting the atmosphere if 14what compact fluorescent lamp (CFL) lighting technology were to be employed. If the OPTZ is adapted and used in an office then, there the probability that a 90% to 95% saving of CO_2 emission to the environment is possible. Future research is recommended towards comparing the results with different office buildings, regions and a longer duration period and probably using different energy savings lighting bulbs. Likewise, calculating the actual amount that can be achieved from the OTPZ zone.
Keywords: CO_2, Office, NOTPZ, OTPZ, POE, Space,

1. INTRODUCTION

About 20% of energy consumption can be reduced by the use of daylighting in Asian regions (Yunus, Ahma and Zain-Ahmed, 2013). The lighting energy consumption is about 25–35% of the total energy provided to buildings in Malaysia (METPM 1989). Studies indicated that typical Malaysian office buildings have Building Energy Index (BEI) of (200-300) kWh/m2/yr. BEI between 65-135 kWh/m2/yr was attainable as demonstrated by Green Energy Office (GEO) building in Bangi and Low Energy Office (LEO) building in Putrajaya (Mohd-Zin, 2005 & Mohd-Zin, 2010). The most important aspect of light for task performance is the horizontal illuminance on the horizontal desk, assuming a normal work task. The lux level required for an office building in Malaysia is 300lux -

500lux as stated in MS 1525: 2019 (Department of Standards Malaysia 2019) code of Practice on Energy Efficiency and Use of Renewable Energy for Non-residential Buildings (Heerwagen, and Orians 1986). Daylight and accessibility to view can increase employees' happiness and productivity and this would in turn help in increasing energy efficiency by reducing the waste (Newsham, et al 2009; Dubois, Demers, and Potvin, 2007 & Tuaycharoen & Tregenza 2007). Despite the availability of luminance in the Asian region most space users and office space design don't utilize the renewable source of energy. Hence, the study aims to identify possible strategies of office window design to an occupant's task area that could enhance the comfort of performing a task (paper-based task and verbal intellectual task) in a private office space. Besides, determine the potential carbon dioxide (CO_2) reduction from the OTPZ.

2. BACKGROUND

2.1 Task Performance

Task performance refers to cognitive performance in this research. Human performance alone is not an adequate reflection of people's response to a daylight stimulus; in that people do not always obtain a correct understanding of the nature of performing a task. Newsham *et al.* (2009) in their proposed linked mechanism map show how some factors affect task performance positively and negatively. These are derived from three basic variables (personal control; luminous condition and non-task surface brightness). Visual capabilities and motivation have effects on task performance. Veitch *et al.* (2007) in an experiment shows that desirable lighting conditions that enhanced visibility will likewise enhance task performance that includes computational and paper-based tasks shown in Figure 1. The enhancement of performing a task to achieve sustainability may not be increased by the presence of a window only, but some task can benefit from the availability of a window (Dodo et al, 2013).

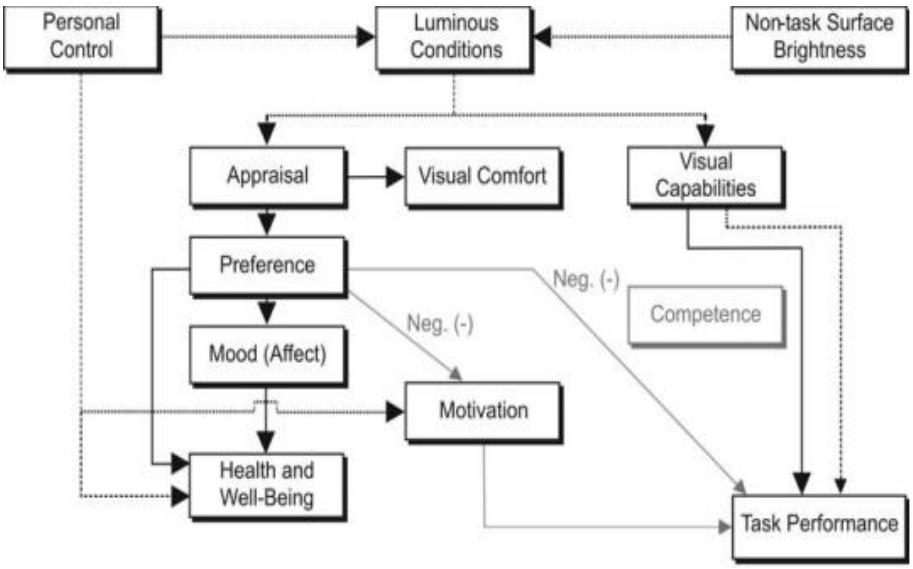

Figure 1: Task Performance Linked Mechanisms Map Source: (Veitch *et al.*, 2007)

2.2 Types of Task Performed in Offices

Veitch and Newsham (1998) categorized task performance in office space based on the level of lighting and activities performed. These categories are; visual performance (computational based task and paper-based task), verbal-intellectual task and post visual performance (reading, eating, sewing and walking). Furthermore, the sustained illuminance levels for general building areas as

given in MS1525: 2019 (Malaysian Standard 2019) as 300lux to 400lux for general offices, stores and shops, reading and writing; for inquiry desk which involves verbal task is 300lux while for infrequent reading and writing is 200lux.

Computational Based Task

These are tasks carried out using various computers be it laptops, desktops and other digitalized computers that require little of lighting since the task itself is self-illuminating as compared to the other two types of task. The computer-based task required high attention.

Paper-Based Task

These are general paperwork carried out in the office premises and ranges from office filling, writing, and all general clerical work excluding verbal and computational work. These tasks require quite an amount of lighting. The difference between computer work and paper-based work is the view of sight; in the paper-based task there is high need of light source be it natural or artificial; while the computer-based task requires little or no lighting source: therefore in the computer work the entire surrounding becomes part of the field of view (Bülow-Hübe, 2008) shown in Figure 2.

Figure2. Difference between Paper-Based and Computer Work (Bülow-Hübe, 2008)

Verbal Intellectual Task

The verbal based task is the task that includes using verbal communication and is carried out in some specific area of work like in mass media; et cetera. This task requires quite an amount of lighting since the task is visually inclined, therefore, the ability to see is a necessity here (reading, comprehension and creative writing).

Post Visual Performance

These are tasks carried out when occupants are at break or decided to unwind after a hectic work, which is (reading, eating, sewing, and walking). These tasks have less or no effect on occupants in office space, as they are performed mostly at break hour depending on the occupants. Lim (2011) indicates that many other office plans used in Malaysia have not included energy efficiency and comfort in the form of architecture, since they were not built on a particular standard, except for certain office spaces that use the Malaysian Standard and other designer-based criteria.

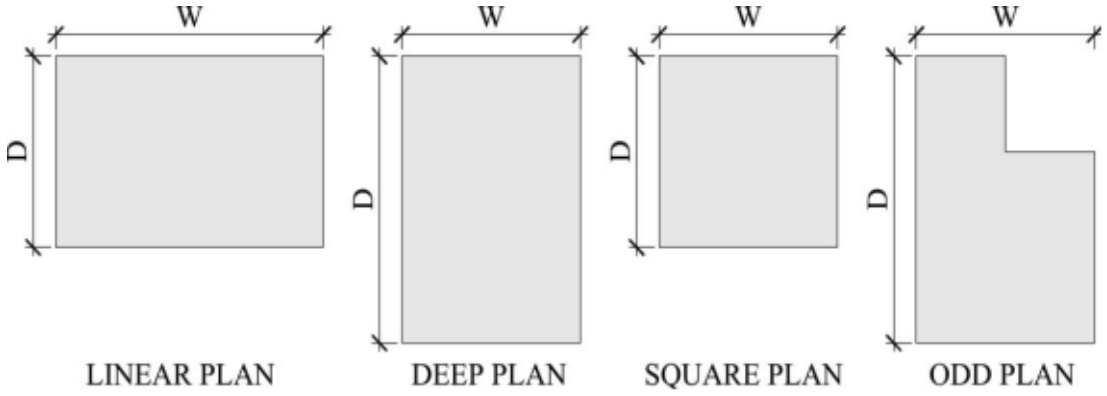

Figure 3: Various Office Plans Shapes Categories Source: (Lim, 2011)

3. The Proposed Optimal Task Performance Zone

After an exhaustive literature review on the essence of ideal office window opening that combines view window and daylight window, about 25% to 40% WWR (Abu Sadin, Nik Ibrahim and Sopian 2013; Zain-Ahmed *et al.*, 2002; Autodesk Building Aperture, 2014) has a strategy from a distance within 6 meters as a rule of thumb (Abu-Sadin *et al*., 2014; The Scottish Government 1993; Dubois, 2001 and Berk 2010) is ideal to attain a comfortable zone to perform a task in private office space by occupants. Therefore, from the OTPZ is defined based on calculation from the rule of thumb as a zone within 1.2m and 4.5m as shown in Figure 5 and 10 which is subjected to the research design and result.

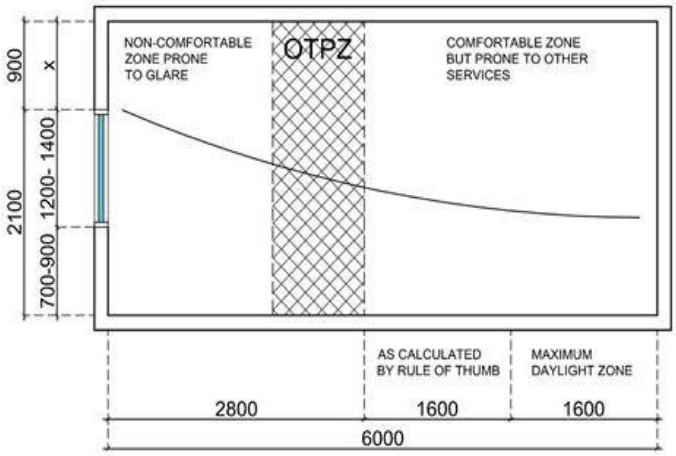

Figure 4: The OTPZ as Predicted by the Research Source: (Dodo, 2015)

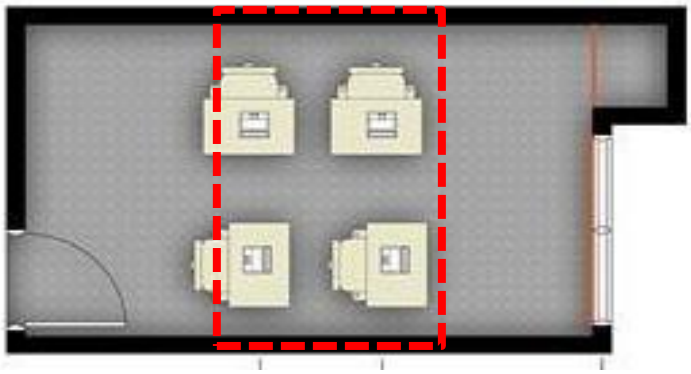

Figure 5: Optimal Task Performance Zone (OTPZ) Source: (Dodo, 2015)

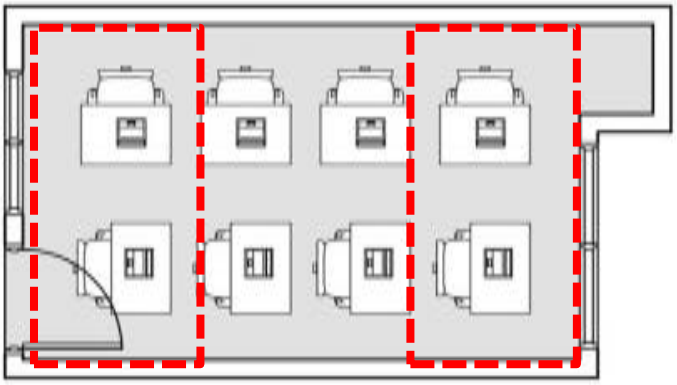

Figure 6: Non-Optimal Task Performance Zone (NOTPZ) Source: (Dodo, 2015)

2. METHODOLOGY

The method used for this study is of two phases: Phase one was the adoption of the OTPZ by (Dodo, 2015) and the second phase is the calculating the carbon dioxide savings from this OTPZ in the calculated building space.

Research method phase one

The research extends the study on task performance zone (Dodo, 2015). The OTPZ methods involved in the experiment are shown by (Aries, Veitch, and Newsham, 2010). An experimental study by (Shin, Yun, and Kim, 2012 & Roufs and Boschman, 1997) on type of view which ascertains that view type and distance of view objects should be fundamental when considering comfort in office space; be it natural or surrogated views. This was based on two experimental treatments; paper-based task test (visual test) and verbal intellectual task test (view test) which was carried out on a single group using a within-group design experimental design. The research made use of the visual test that was adopted by (Hellinga, and de Bruijn-Hordijk 2009) who used a visual test to control text quality metrics for visual display units. The visual test technique which is a quality metrics for visual display units that were used in this research as propounded by Roufs and Boschman (2017) is shown in Figure 7 and figure 8. This was deployed to test the occupants' task performance.

KhuIijkzltpVYICCAekDw he t3 TkW3rm8U yaBpE O2B L8Y A5 She PQtb 90DViRCDG 1H pSMyEqZz 6F PPoL0sATQesa ANUU VLH Ou1p2JBE vbR 34Wxxt7 SA9mr DmPETLV 2uO2 7phnFd2oyT 83ee zKo8h KyiTJgALvXMu 6Kugm 3ElkxsOWhCK1FTMA T6 LuGF5 ad 67Jhsd H0jkHv ssAq U 8dw khuIijkHCsnGdYIMQEITSfoyW 5LN 6Bv0 98GFhw Cn x9gUiaH3 fySFoauaxjUekbKQz 2uZa MmnCN 4t K1Ity677 PpMnKhuIik dRbK1 Ez 33Q 6w fvVR 7B gyz Ns5 5Ami 7T5k 6bc2 ZH1 Ko1L1 GwJ9 ECKYm Xob3m t9 SU ZR el ys HsbesrfU9 nToPDFNnOo 67QqwW rMI0oizFL8d a2Z sD AK5R1 Q8jiI wBeeA L2Rz0

Figure 7: Alphabets Set (A) Used for the Paper-Based Task Test Adapted From; (Roufs and Boschman 2017)

KHUIIJK ZLTPVY ICCAE KDW HE T3 TKW3RM8U YA BPE O2B L8Y A5 SHE PQTB 90DVIRCDG 1H PSM YEQZZ 6F PPOL0SATQESA ANUU VLH OU1P2JBE VBR 34WXXT7 SA9MR DMPETLV 2UO2 7PHNFD2OYT 83EE ZKO8H KYITJGAL VXMU 6KUGM 3ELKXSOWHCK1FTMA T6 LUGF5 AD 67JHSD H0JKHV SSAQ U 8DW KHUIIJK HCSNGDYIMQEITS FO YW 5LN 6BV0 98GFHW CN X9GUIAH3 FYSFOAUAXJ UEK BKQZ 2UZA MMNCN 4T K1ITY677 PPMN KHUIIK DRBK1 EZ 33Q 6W FVVR 7B GYZ NS5 5AMI 7T5K 6BC2 ZH1 KO1L1 GWJ9 ECKYM XOB3M T9 SU ZR EL YS HSBESRFU9 NTOPDF NNOO 67QQWW RMI0OIZFL8D A2Z SD AK5R1 Q8JII WBEEA L2RZ0

Figure 8: Alphabets Set (B) Used For the Paper-Based Task Test Adopted From(Roufs and Boschman 2017)

Research method phase two

This is the phase that determines the amount of CO_2 reduction from the OTPZ. The study was carried out using an average CO_2 emission (in Grams) for producing 1KWh electricity (The Environment 2010). The calculations were based on using CO_2 Produced (Coal Based Power Generation) for an annual KWh Consumed (@8hr/day) using lighting technology (800 Lumens) and this was related to CO_2, which is assumed to be accountable for climate change, is produced at 7500 tons for 1 Mega Watt mini electricity generating station see figure 9 and 10 as further breakdown is shown (The Environment 2010)

Source	Grams of CO2 produced
Coal	870
Oil	650
Natural gas	487
Nuclear energy	16
Hydropower	20
Wind energy	11

Figure 9: Average CO_2 emissions (in Grams) for generating 1KWh electricity Source: The Environment (2010)

Lighting Technology (800 Lumens)	Daily Kwh Consumed (@8hr)	Annual Kwh Consumed (@8hr/day)	Co2 Produced (Coal Based Power Generation)
Incandescent (60 Watts)	0.48	175.2	152.42 Kg
Halogen (42 Watts)	0.34	124.1	107.96 Kg
CFL (14 Watts)	0.11	40.15	34.93 Kg
LED (9 Watts)	0.07	25.55	22.23 Kg

Figure 10: Average CO_2 emissions (in Grams) for generating 1KWh electricity Source: The Environment (2010)

3. RESULTS AND DISCUSSION

The negligence of human values as one of the important criteria in rating buildings performance is of another importance to the development of a green built environment. To incorporate the human value in these green buildings rating system, a POE of the building is required to be carried out to get feedback for future improvement either on green or conventional buildings (Meir, et al. 2009 & Ganjbakhsh 2010). Occupant's visual task performance level depends on the following two aspects: the characteristics of the task and the light conditions. Windows play an important role to people who use enclosed spaces: aesthetically pleasing, energy-reducing and comfortable healthy environment. The window performs two main functions of allowing ventilation and daylight (Djamila, Ming & Kumaresan, 2011).

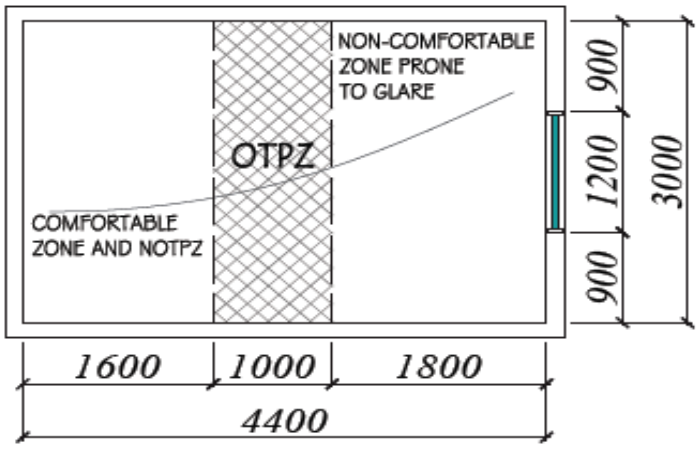

Figure 11. Predicted OPTZ and NOTPZ from the experiment Source: (Dodo, 2015)

Light plays an important role in the visual system, without light we cannot see anything. Daylight is useful to man when it is glare-free external luminance of up 20,000lux is available to be tap from in Malaysia depending on the sky conditions which is mostly intermediate based (Yunus, Ahma and Zain-Ahmed, 2013 and Djamila, Ming & Kumaresan, 2011). While the required amount for an occupant to perform a task comfortably in office settings is 3000lux to 350 lux (Department of

Standards Malaysia 2019). It is paramount to note that if design approaches utilize the Predicted OPTZ from Figure 11, an amount equivalent to 304. 82Kg of CO_2 will be saved from polluting the atmosphere if you were to use an Incandescent (60 Watts) as space require 2 (60 Watts) Lighting Technology (800 Lumens) on a daily kilowatt consumption for 8hrs. Meanwhile, if the same space was lit by 14what CFL lighting technology, then a reduction would be (34.93Kg) X 2 saving of CO_2 emitted to the atmosphere see Figure 9 & 10 (The Environment (2010).

One of the long term benefits of proposing the OTPZ is that greenhouse emissions are also reduced by reducing fossil fuel use. Although CO_2 is not necessarily harmful, it is the primary cause of climate change, which has its effects on public health. These include heat stress, more intense storms, drought and flood extremes, the spread of infectious diseases, and even nutritional deficiencies.
CO_2 is harmful to human health from burning fossil fuels. As the biggest public health issue of the century, the consequences of climate change have been identified. It has been developed that all fossil fuels lead to global warming if their emissions are emitted into the atmosphere (Watts et al. 2018).
The health and economic co-benefits that can be gained through carbon reduction interventions by adapting the OTPZ as one of the criteria to be addressed in the most building in form of a code. The reductions in emissions of air pollution are immense as a result. The calculation tool for Carbon Reduction Benefits on Health (CaRBonH) has been explored across the globe.
Susceptible subgroups of people who are exposed to air pollutants, such as children and sick and elderly people, such as a result of not reducing the amount of CO_2 and its equivalent allowed into the atmosphere pose the risk of adverse health symptoms ranging from minor pain to more severe life-threatening conditions is higher. (World Health Organization 2018).

4. CONCLUSION

The amount of CO_2 saving from the predicted OPTZ can lessen the cooling energy used for building by about 10% to 20%. The findings denote the importance of daylighting usage in office buildings and highlight several aspects of improving building design for construction professionals and grey areas for energy policymakers in Malaysia. Then considering CO_2 in more detail, if you have a 100 watt light bulb that is left switched on all year, then during the year 750kg of CO_2 will be produced by the generating station; now it using artificial daylight will continuously keep a light bulb switch on every day then that is also capable of generating 125kg of CO_2. So, if energy-saving light bulbs (CFL) are used in OPTZ which will only consume 80% of the energy then a saving of about 100kg every year CO_2 emissions into the environment is achieved per an OPTZ. On the contrary, if the OPTZ is implemented meaning artificial lighting system is used only when necessary, then there the probability that a 90% to 95% saving of CO_2 emission to the environment is possible. Also, the quantified health benefits of reduced pollution include avoided cases of disease (morbidity), less premature deaths and life-years gained among the exposed population due to an increase in life expectancy. The finding of this study is subject to future research as the results were obtained within a period less than a year and to confirm the findings more regions an types of office need to study.

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