ABSTRACT
The growth of automobile population in Kuala Lumpur is an important issue for car parking spaces especially commercial buildings. The large multi-storey and underground car parks seem to offer good solution nowadays. Undeniably, indoor air quality (IAQ) is a vital element in the underground car park. It is so important due to its effects to the human beings. It can affect someone's health condition indirectly if someone stays in the environment such as underground car park with the poor IAQ for a long time. This problem can be reduced by providing a better ventilation system in the underground park so that the IAQ can be improved and increased well. Provision of adequate mechanical ventilation is essential to maintain an acceptable air quality in underground car parks. This paper addresses concerns about psychological aspect on indoor air quality in underground car parks. This paper addresses concerns about psychological aspect on indoor air quality in underground car parks associated with ventilation system and design layout. Users in a sample of underground car parks were interviewed in the course of a questionnaires survey dealing with nuisance occasioned by the pollutant mainly due to vehicle emissions. Accumulate two case studies measured data is important for the further discussion and developments to overcome the problem. This paper gives a fundamental data for the help of the future refinements.

KEYWORDS
Indoor Air Quality, Ventilation, Design Layout, Underground Car Park

INTRODUCTION
The growth of automobile population is an important issue in many urban cities around the world. It creates not only a horde of problems such as indoor air quality and noise pollution, but also affected the demand of parking spaces as in any city, land is scarce and expensive resource that has to be utilized to its fullest value. Therefore, multi-storey car park has become a solution in order to optimize the usage of the land. Varieties of parking spaces are designed such as underground (basement), surface (ground level) and above ground (elevated and usually multi-storey complex). Underground car parks are expected to be much more constructed in future. This is due to the current scenario of the developed cities where they prefer to build the main building spaces rather than erecting an elevated multi-storey car park complex on the land provided which this is believes will affect the aesthetic value as well as the environment of the whole development. An underground car park is defined as under a street or an open space and it is a basement to a building which includes any floors constructed under ground level (Burnett J. and Chan M.L 1997).
An enclosed underground car park which constructed under large buildings needs special ventilation requirements since the presence of natural ventilation is insufficient. Furthermore, the enclosed design will limit the interactions through the infiltration and exfiltration processes. Indeed, lacking of good ventilation system present several problems such as thermal conditions, air quality and others. Thus, mechanical ventilation is required to dilute or remove exhaust pollutants generated by vehicles with engines operating within the car park (Environmental Protection Department 1996).

Poor indoor air quality (IAQ) aspect is the common problem facing in underground car park. If the hazardous gases keep entrapping and accumulating in the car ground without taking any action, these hazardous gases are harmful and they would affect people health. As a result, some wise actions are needed to be taken so that the entrapments of waste gases in underground car park can be overcome (Tay, K. L 2002). Undeniably, a good ventilation system is needed corresponding to the problem mentioned above.

The aim for this research is to study the ventilation system in the underground car park and its effect towards the quality of indoor air within this environment. Therefore, this research will study on indoor air quality in underground car park associated with its ventilation system and investigate the consequences of indoor air quality issues to the building users.

Duration of Occupants in the Car Park
This can either be based on a study for an existing car park or on reasonable estimate figures specific to the site. For example: 5 minutes to drive in and park, 5 minutes to collect belongings and walk out of the car park, 5 minutes to walk back to the car and load shopping, 5 minutes to drive out of the car park and, say, 5 minutes spare. This gives a total time of 25 minutes exposure period. This figure would then be used to calculate the 8-hour TWA exposure limit (Health and Safety Executive 2000).

Ventilation System in Underground Car Park
Basement or underground car parks shall be provided with mechanical ventilation such that the air exhausted to the external atmosphere should constitute not less than six air changes per hour. In the Uniform Building By-Law 1984 [G.N.5178/85] stated that air extract opening shall be arranged such that it is not less than 0.5 meters above the floor level period system (Legal Research Board 2003). This dilution principle in car park ventilation design is to maintain a safe level of carbon monoxide and nitrogen dioxide emitted from the vehicles during peak hours as well as under the worst foreseeable operating conditions, such as queuing of vehicles within the car park.

METHODOLOGY: FIELD SURVEY
Measurement Subject
Two shopping complexes have been identified and related information is obtained from interview with building managers. The location is located at Kuala Lumpur which the measure object is underground car parks shown as Figure 1, 2 & 3 and Table 1 & 2.

Questionnaires Surveys
Post occupancy evaluation (P.O.E.) which was done by conducting one hundred questionnaires for each case study which were distributed to the car park users and workers.
Questionnaires survey terms are shown in Table 3. For the survey method each of type we decided to distribute the questionnaires and collect after the questionnaires were filling up.

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<th>Table 1 Characteristics of field measurement</th>
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<tr>
<td>Type</td>
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<th>Table 2 Ventilation system of field measurement</th>
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| A    | • Using two different methods in providing the mechanical ventilation systems which are supply-only ventilation system and supply and exhaust ventilation system (balanced mechanical ventilation system with fresh air supply and exhaust air extracted).
    | • Nicotra tube axial fan, silencer inlet, acoustic inlet, outlet silencer and non return damper. (Refer Figure 4) |
| B    | • Supply and exhaust ventilation system with single phase squirrel motor (Refer Figure 5) |

<table>
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<th>Table 3 Questionnaires surveys terms</th>
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<td>1. Satisfaction of Air Quality</td>
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<td>2. Comfortable inside Car Park</td>
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<td>3. Type Discomfort Experienced in Car Park</td>
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<td>4. Cause Discomfort Experienced</td>
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RESULT ANALYSIS AND DISCUSSION

Comparisons of Case Studies

In the two chosen case studies which are underground car parks from Building A and Building B, a comparison was done in the aspect of ventilation system and its design layout. Both of the underground car parks from Building A and Building B use the mechanical ventilation system. The process of the mechanical ventilation system is meant to supply the fresh air and extract out the exhaust air. The motors with axial fans function as pumps to supply the fresh air and extract the exhaust air through the inlet and outlet. Basically the ventilation systems in both underground car parks is using the same method which is balanced mechanical ventilation system with fresh air supply and exhaust air extracted. But the efficiency of the ventilation system is different due to many external factors.

Ducting design in Building A which provides the air supply is not covered the whole car park area. Only 2 zones out of 6 equipped with balanced mechanical ventilation system. This caused the thermal condition of Building A is higher than Building B. Besides, there is no opening for natural fresh air and is fully enclosed area. At the first place, car park at Building A is not fully depending on the mechanical ventilation where 70% of the total area is using natural fresh air. The problem occurs when the second phase of the construction project for Building A commenced and still in progress. Most of the openings for natural fresh air are blocked with the new structures and this cause the ventilation...
inside it becomes worst. A new mechanical air supply is needed to enhance the ventilation condition in the underground car park.

Figure 1. Ventilation System used in Building A Underground Car Park and its Distribution

Figure 2. Building B Car Park Layout
Post Occupancy Evaluation Analysis

According to Building Regulations adopt the Health and Safety Executive; EH40/2000 – Occupational Exposure Limits 2000-1, the time period inside car park should not more than 15 minutes period and the level of carbon monoxide is not exceeding the peak exposure of 200 ppm. Regarding to this reason, the level of carbon monoxide should be below 200 ppm because in Figure 6, majority of the
participants spent about 10-30 minutes of their time in the car park. In Building A, 57 percent of them used 10 to 30 minutes to leave off the car park area whereas 62 percent of survey participants will spend 10-30 minutes in Building B.

The percentage of the participants who took their time about 10 – 30 min in Building B are higher than Building A. This scenario occurs most due to the signage provided in the car park. Once the users park their car, they need some times find their way out. If compared to Building A, Building B needs to provide more entrances and improves the signage so that it can be more accessible. Although the car park areas in Building A is bigger than Building B, but the time taken to enter the main building is quite the same with Building B due to the signages and number of entrances provided.

The workers in the shopping complex also involved in the post occupancy evaluation. Most of them chose the answer of within 10 minutes of time taken because they were quite familiar with the design of the underground car park. This group of people has no problem with the signage problem and they can leave the car park easily. By referring to the time period 30 minutes to 1 hour, the percentage of Building A’s underground car park is more than Building B which stated 17 percents whereas Building B is only 12 percents. Users in Building A’s underground car park spent more time because they cannot remember where they park their cars since the compound of the car park is too big.

Meanwhile, Figure 7 shows that the majority of the participants for both buildings said that air quality in the underground car park is poor which dominated 45 percents and 50 percents each. Moreover, there are 18 percents of participants from Building B and 19 percents of participants from Building A complain that the air quality is terrible. They complain that the air is smelly and dirty due to the present of odor and dust. Furthermore some of them complain that they experienced some discomfort feelings such as breathing problem and sneeze.

In Figure 8, result shows that most of the participants disagree with the comfort level in both buildings. The results show in the bar chart is quite similar. The discomfort feelings for both buildings are as high as 81 percent and 79 percent respectively. The discomfort feelings experienced by these occupants are shown in Figure 9. All types of discomfort listed in the figures are the same with the symptom for the sick building syndrome and the building related illness.

The most serious discomfort experienced by the survey participants in Building A is breathing problem. In Building B, the most serious discomfort is nausea. The most serious discomfort experienced by these two underground car parks is different due to the environment in the car park.

Figure 10 shows the causes for the above discomfort feelings. The main causes in Building A are air temperature and automobile exhaust. These two causes dominated 69 percents from the total of the survey participants. Refer to the air quality in the Building A underground car park in the previous analysis, it shows that air quality in Building A underground car park is worse than the Building B. As result, it brings many discomforts to the car park users. Users mostly encounter problem such as irritation and stuffiness due to the high air temperature.

Besides, there are also 69 percents of the survey participants claimed that causes to discomfort experienced is automobile exhaust. This is why the discomfort such as breathing problem is the highest rate for the survey participants in Building A underground car park. The lowest cause of the discomfort selected by the survey participants is the wall paints and the microbial growth. These two causes only dominated 6 percents. On the other hand, microbial growth is the second highest percentage selected by the survey participants in Building B underground car park. It dominated 47 percents from the total of survey participants. That is why the nausea encountered by may of the survey
participants; they are all affected by the microbial growth in the car park.

Apart from that, the highest cause of discomfort experienced is bad lighting condition which dominated 59 percents. The bad lighting means the lights are not sufficient or there are too dim. As a result, the car park always in dark condition and it makes car park users feel insecure while in the car park. Next, the cigarette smoke is also dominated a quite high rate which is 42 percents. Cigarette smoke is the main factor to cause coughing and breathing problem to the car park users.

![Figure 6. Time Period inside Car Park](image)

![Figure 7. Satisfaction of Air Quality](image)

![Figure 8. Opinion of Comfortable Inside Car Park](image)

![Figure 9. Type of Discomfort Experienced](image)

![Figure 10. Causes of Discomfort Experienced](image)
CONCLUSION

Research Findings

We can conclude in three aspects which are car park design, ventilation system design and the users’ duration staying inside the underground car park. Each of the findings has the effects to the indoor air quality. As a result, each of the findings should be emphasized on and should be put attention seriously so that indoor air quality can be improved in the future.

(i) Indoor Air Quality Affected by Design of the car park

A good car park design layout can minimize the emission from the vehicles. One of it is the number of exit and entrance points of the vehicles to the car parks to reduce the numbers of cars queue in the driveways. Second is the provision of the signages within the car parks areas. Poor signage causes car park users spend longer time in the car park especially for those who are not familiar with the buildings and thus emission from the vehicles will be increased as well.

(ii) Indoor Air Quality Affected by the type of Ventilation System

The underground car park of Building B has better ventilation system than Building A. This is because it used the fully mechanical supply air for the whole areas compared to Building A where only 2 zones used this type of mechanical ventilation system. It is therefore, for any fully enclosed car parks areas are recommended to use this type of system.

(iii) Users of the car park will not encounter discomfort if they spend short period in the underground car park

Many of the respondent claimed that they encountered discomforts feelings if they stayed in the underground car park for quite long time. This is because the longer they stayed, the higher chances for them to expose to the environment in the underground car park and the more chances they experienced discomfort feelings. Building A car park covers a big whole areas and respondents claimed that they almost get lost and has forgotten which level or which zone did they parked their cars and time become longer. As a result, the chances they get discomforts will be higher and some wise actions should be taken to prevent such unwanted incident.

REFERENCES

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