HIGH EFFICIENCY SWITCH SOCKET OUTLETS DISTRIBUTIONS IN BUILDINGS EMPLOYING DIVERSITY FACTORS METHOD

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ABSTRACT

The requirement for the number of switch socket outlets to be installed in a building has always come from the customers. In practice, this requirement will normally be specified by the electrical consulting engineer engaged by the clients. Later, the drawing for these socket outlets will be checked and approved by a professional engineer with practicing certificate (PEPC) who holds full responsibility on the design. In order to approve the drawing, the PEPC has to ensure that the design complies with the safety standards of electrical installations in a building. The question is whether the design really meets the standards and safe for use for the public – when there is no standards mentioning the optimized outlets' distributions in a building. Another, it is rather time consuming and challenging to determine the correct number of socket outlets in every design or drawing due to the unavailability of a reference guide. The existing electrical wiring standards left the decision on specifying the number of socket outlets to the design engineer. As a result, without any guides, there will be no benchmarking for the safe and optimized design. Thus, in this paper, a study of applying the diversity factors method to determine the efficient number of switch socket outlets distributions in a building is conducted. The study also looks into the efficiency of the socket outlets usage using diversity factors method.

Keywords: Switch Socket Outlets, Diversity Factors, Energy Conservation, Socket Outlets Efficiency, Optimization.

INTRODUCTION

Nowadays, the electrical engineering consultants for building services have a set of rules to follow in designing the electrical final distribution circuits in a building. The term "final distribution circuits" refers to the lighting and power circuits in an electrical low voltage services in a building. It is in the power circuit that the switch socket outlets are designed. At present, there is no reference guide of the ideal diversity factors applied when determining the number of optimized switch socket outlets in certain room or building. As diversity factor is used in determining the size of cables to be installed, diversity factor should also be used in determining the number of socket outlets in the building. Thus, a problem with over-design and under-design could occur in this project (Linsley, 2013). As a result, the costs of implementing a project could be higher than what is actually required.

The determination of the diversity factors is important in order to prevent this over-and-under design from taking place in any projects. The diversity factor determination would affect the sizing of sub-main cables, distribution boards, and ultimately the size of transformers and switchgears from the power producer side (Tenaga Nasional Berhad, TNB). Practically, when cable size increases, costs would also increase.

Previously, the consultants followed the British Standard (BS) 7671, IEE Wiring Regulations in designing the electrical services in buildings. At present, since the Malaysian Standards (MS) are available, the MS standards are to be used together with the Electricity Supply Act 1990, Electricity Regulations 1994, and other standards that are deemed necessary for the electrical installations in buildings. These standards are, namely, the MS/IEC60364:2003 Standard: Electrical Installations of Buildings, MS1936:2006 Standard: Electrical Installations of Buildings – Guide To MS/IEC60364, and MS1979:2007 Standard: Electrical Installation of Buildings – Code of Practice are in force since 1st July 2008. The problem with these standards is that they do not specifically mention to apply diversity factors when designing switch socket outlets in the building. The diversity factor is only applied in determining the size of the sub-main cables laid from the distribution board to the final circuits (Tenaga, 2008).

To date, the author still could not find any literatures studying the diversity factors for the design of switch socket outlets distributions in a building. The previous literatures only set guidelines of using certain diversity factors which are purely based on common sense without any specific study. The IEE Wiring Regulations, 17th Edition, for example, is the reference point of this wiring standard for commonwealth countries, does not specifically mention about the diversity factors. This regulation only suggests the diversity factors that the electrical consultant should use when designing the sub-main cabling connecting the final distribution circuits in a building. The standard socket outlets circuit arrangements was removed from the 16th edition of the IEE Wiring Regulations in 1991 and the designer has to determine exactly the required number of socket outlets to be installed in the building (Yu, 1995).

Situations in Malaysia as compared to other countries in the world might be different due to certain factors such as culture, environment, population, temperature, and etc. It is also found out from the literatures that in this country, there is no study to tackle this issue. The following questions will be addressed in identifying the current practice in determining the quality factors in designing the switch socket outlets distributions in building:

1. First, "Do the consulting engineers use any standards or guides in determining the number of switch socket outlets to be installed in a building?"
2. Second, since the public safety and health should be taken care of when designing such services, the following question shall be addressed: "Does safety of the users is taken into consideration when allocating the switch socket outlets in a designated location?"
3. Third, we would look into another factor that affect the cable sizing which could also affect the installation costs of such services that leads to the following question: "Do the number of switch socket outlets installed in a building significantly affect the efficiency of the electrical low voltage services as a whole?

PROBLEM STATEMENT

From the past data, statistics have shown that fire due to switch socket outlets ranked second in the list of causes. This cause is normally due to the overloading of the socket outlets in use. Currently, there is no guideline on the optimized number of switch socket outlets required to be installed in a particular type of room in a building. The guidelines that exist nowadays only specify the limit of socket outlets that can be installed in one circuit; either in a ring or a radial circuit - thus left the decision of allocating the number of socket outlets to be installed to the design or professional engineers. The process would sometimes take more time for the engineers to figure out the optimized number of socket outlets to be installed. Not only time, but also design efficiency also in question - when the design is based on intuition or trial-and-error. Due to this reason, later, the consultants could still have a doubt of the number of socket outlets he has allocated in the building.

When socket outlets are not sufficient in a room, users tend to use socket extensions to fulfill their needs. This would increase the loads in that particular socket and final circuit connecting the socket outlet with the distribution board. The normal design power for a socket outlet is normally specified at 250 Watts to 300 Watts – depending on the type of building. If for example, the user adds one extension cable with four socket outlets, and then connects a hot-water dispenser, washing machine, and refrigerator using this socket extension, then the socket is overloaded. The fundamental cannon of the engineers responsibility towards the public which is mentioned in the Code of Conducts of a Professional Engineer that is "…to Uphold Paramount the Safety, Health, and Welfare of the Public" would be violated in this case (Malaysia, 1990). It is the engineer's obligation to ensure the design is safe for use. The professional engineer must assume that the users or publics are ignorant about the overloading of the circuit if socket extensions are to be used. Thus, it is the professional engineer's responsibility to ensure that the design has met certain standards for safe use before he or she can approve the drawing for construction. However, since there is no guideline or study done in this area, the determination of the number of distributed socket outlets is undoubtedly a problem. The professional engineer is actually still left with the risk of over-and-under designing the electrical infrastructure. Thus, in order to avoid all these issues, a model representing the socket outlets requirement has to be formulated.

Over-design of switch socket outlets would result in unnecessary project's cost increase and inefficiency of the outlets usage, while under-design could cause insufficiency of outlets availability and infrastructure when need to be used. Thus, in order to avoid these problems, my research would be focusing on finding the optimized diversity factors for the switch socket outlets distributions designs. These factors could be used by the design or professional engineers whenever they design socket outlets distributions in a building.

METHODOLOGY

There are few methods that we can employ in determining the diversity factors. For example, we can calculate the number of SSO based on the area of the room. But using this method alone could not guarantee that the diversity factors be used universally. Thus, we have to combine few methods and converge into the most accurate model. After discovering the model for the diversity factors, testing on the model accuracy has to be done. Few methods to test the model accuracy and reliability can also be carried out such as via computer simulations, interviews with people, and site surveys with the existing projects.

The research objectives could be achieved by studying the existing design, interviews with the consulting engineers, and survey questionnaires with the users of the socket outlets. From here, the new diversity factors representing the switch socket outlets requirements in each building will be formulated. This mathematical modeling can then be tested via software simulation to look at the relationship of the model with the existing socket outlets design. In this case, the existing power-layout plans of an electrical low voltage services in building are required to be studied. Few plans representing residential and office buildings will be required for this purpose. Then, after getting the number of optimized socket outlets from this mathematical model representing the diversity factor, on-site survey will be conducted. This is done through the comparison between the new socket outlets and the existing ones; through interviews with the users of the outlets. The results of this comparison would explain whether the diversity factor's model represent the actual requirement of the users' needs of socket outlets. There might be certain other parameters that could limit the new models of the DF as the time goes by, for example, the new inventions of equipment that might probably be available in the future. This other factor might affect the accuracy of the DF model that leads to the inaccuracy of this model in the future.

By studying the existing design we could gather data regarding the number of SSO that a room normally have. This is normally done logically and purely based on the experience of the designer to select the number of SSO to be installed in a particular room. This is prepared to compare the new socket outlets design with the existing ones through interviews with the users of the outlets. The results of this comparison would explain whether the diversity factor's model represent the actual requirement of the users' needs of socket outlets.

The diversity factors are the constant multipliers that are used to determine the optimized number of SSO to be installed in a particular room or area in a particular building. These factors will help designers to speed up design processes and to provide guidelines for the SSO determination. With the diversity factors table provided to each designer, the process of designing would be more efficient and less time consuming. The diversity factors table is just a guide and not mandatory to follow since customers might have extra requirements for the SSO to be installed in the particular room. Else if not previously determined by the customers and designers, the diversity factors table can be used as a comprehensive guide when designing the SSO in any projects. Once the diversity factors are determined, the numbers of SSOs can then be found as follows:

Table 1: The application of diversity factors in guiding designers in a particular design.

Building Type	Room Type	Diversity Factors (DF)	No. of Occupants in the Room (Fixed)	No. of Occupants in the Room (Mobile)	Suggested Number of SSO to be Installed
Single Floor Office	Manager Room	3	2	-	6
	Director Room	4	1	-	4
	Staff Cubicle	3	10	-	30
	Pantry	3	-	2	3
	Toilet	2	-	2	2
	Waiting Area	3	-	3	3
	Meeting Room	6	-	10	6
	IT Room	8	-	3	8

It is often difficult and time consuming when the guide (as above) to determine the number of SSO is not available. This is because an experience designer would need to study the area of the room, see the furniture layout, and logical thinking to allocate the optimum SSO in the room.

Interviews with the consulting engineers would yield the normal practice in determining the number of SSO the engineer would allocate for a particular room. Designer who is very experienced would use his or her experience and knowledge in determining the suitable number of SSO to be installed in a particular room. His judgment would be based on the past experience on the same type of projects and data or information gathered on the requirement of devices to be connected in that particular room. From this interview, we could get an approximation on the number of SSO that the designers would allocate and can be the benchmark and comparison table with our findings. Table below shows the projected diversity factors formulated from the interviews with the professional engineers or designers. (Shows projected diversity factors table for benchmarking purpose).

Table 2: The approximate numbers of SSO installed at the existing buildings differ from room and building types.

Building Type	Room Type	SSO Quantity Installed
Single Storey House	Carpark	-
	Living room	3
	Master bedroom	2
	Single bedroom	1
	Double bedroom	1
	Toilet	-
	Kitchen	2
Double Storey House	Carpark	-
	Living room	3
	Master bedroom	2
	Single bedroom	1

	Double bedroom	2
	Toilet	-
	Kitchen	2
Single Level Office	Director Room	5
	Manager Room	3
	Staff Cubicle	3
	Meeting Room	4
	Guess Waiting Area	3
	Store Room	1
	Pantry or Kitchen	2
	Toilet (Male or Female)	-

Power Layout plans from previous projects will be studied to gain information on the number of SSO installed at a particular room. In this case, the existing power-layout plans of an electrical low voltage services in building are required to be studied. A few plans representing residential and office buildings will be required for this purpose. Then, after getting the number of optimized socket outlets from this mathematical model representing the diversity factor, on-site survey will be conducted. There might be certain other parameters that could limit the new models of the DF as the time goes by, for example, the new inventions of equipment that might probably be available in the future. This other factor might affect the accuracy of the DF model that leads to the inaccuracy of this model in the future.

Room types have to be classified and grouped in order to simplify the diversity factors determination and application. To simplify the determination of the diversity factors, the room types need to be grouped and defined properly. Every building has almost had a similar room type with each other (Malaysia, 2012). For residential building, the room type is almost similar – only the size and status of the room is different. For lower-end residential room like the low cost flat, the number of SSO required might not differ much than the high-cost condominium. There is a tendency that more SSO will be installed at the high-end dwelling units (e.g. bungalow house) than the low-end units. However, this does not mean that the number of SSO in the high-end units is optimized. In this scenario, the number of SSO installed at the high-end units might just be oversized. Applying the diversity factors during the design of any new development would also be easier using a simple table that represents all types of building. The expected table of diversity factors might be as follows:

Table 3: The expected DF that should help designers in allocating the quantity of SSO in the buildings.

Building Type	Room Type	Expected DF
Residential	Carpark	1
	Living room	3
	Master bedroom	2
	Normal bedroom	2
	Store room	1
	Kitchen	3
	Toilet	1
Office	Director room	5
	Manager room	4
	Staff cubicle	4
	Reception area	4
	Meeting room	6
	Store room	2
	Pantry	3
	Toilet	1
Gallery/Showroom	Guest waiting area	3
	Reception platform	6
	Praying room	2
Bank	ATM area	3
	ATM machine cubicle	2
	Customer waiting area	3
	Staff cubicle	3
	IT room	6

School/University	Classroom	6
	Staff cubicle/table	3
	Lecture hall	8
	Lecture theatre	8
Restaurant	Kitchen (depends on devices)	6
	Customer area	3
	Office room	3
	Store room	2
	Toilet	1
Shops	Cashier counter	4
	Customer area	3
	Office	3
	Store room	2
	Toilet	1

The above table gives the optimized diversity factors based on the type of room in the building. Similar DF can be used to represent same room type in different buildings. For example, should there be any office in the restaurant; the number of DF shall be the same as the Office DF.

All of the possible parameters which would have an effect on the diversity factors have to be determined, for example, number of people normally in the room, dimension (area) of the room, purpose of the room, status of the building (or room), and etc. The research is focused on getting the DF that can represent a specific room and have simpler model that can represent the specific room.

A formula will be formulated based on the forecasted DF gained from the experience of the designers to get the optimized DF. From here, the new diversity factor representing the switch socket outlets requirement in each building will be formulated. This mathematical modeling can then be tested via software simulation to look at the relationship of the model with the existing socket outlets design.

The optimization of the DF will first be simulated using Matlab simulation. Matlab simulation will give an idea on how the parameters that we define in the model are sufficient to learn the behavior of our DF.

The second method to verify whether the DF factor is optimized is using the multi-objective optimization method. A multi-optimization method is a method that we can use to get the optimized model that represents every room's diversity factor. This method will help us in getting the right mathematical model of DF after considering the major parameters that might have an effect on the optimized number of SSO installed. Once the model is generated, we can test the model via simulation. This simulation program should be able to confirm that the model we generate is close to the actual requirement of the SSO that we are supposed to install in any building.

One of the challenges in this research is on how to ensure that the DF is really optimized. Optimization on DF also means that we are not overdesigning the number of SSO installed. Overdesign means more cost incurred on the project. On the other hand, under-design results in the addition of extension SSO which cause circuit overloading. Thus, the right tests for the over-and-under-design will be conducted to ensure that the DF that we discover is really optimized. Thus, we should not only depend on the multi-objective optimization method to get the optimized DF.

PRELIMINARY RESULT AND DISCUSSION

The research objectives could be achieved by studying and collecting data form the existing design, processing and analyzing the data, studying the relationship between each variable with the SSO design, formulating DF mathematical models for each room, testing the mathematical models, optimizing and validating the models.

Some preliminary data were collected in this research. This is done to learn whether this study is practical to be conducted. Thus, few projects were selected and studied. The process of data collection starts with compiling and classifying the required projects into few sub-categories as follows:

1. Office – Bank Branch (Occupants: 10 to 15 people in a floor)
2. Office – Small Office (occupants: less than 15 people in a floor)
3. Office – Large Office (occupants: 15 to 50 people in a floor)
4. Shop – Small Shop (occupants: 3 to 5 people in a floor)
5. School (occupants: depends on building type such as office, classroom, hall, and etc.)
6. College (occupants: depends on building type such as office, classroom, hall, and etc.)
7. Residential – Single Storey Terrace House (occupants: less than 8 people)
8. Residential – Double Storey Terrace House (occupants: less than 8 people)
9. Residential – Single Storey Bungalow (occupants: less than 8 people)
10. Residential – Village House (occupants: less than 8 people)

Office – Bank Branches

In this study, the banks consist of 16 branches all over Malaysia. The drawings that we are interested in studying are such as the Power Layout Plans and Single Line Diagram. In order to illustrate on how this study is conducted, five of the bank branches are chosen. This pilot study involved five of the bank branches as follows:

1. Jinjang Utara Branch.
2. Taman Megah Branch.
3. TTDI Branch.
4. Sime UEP Branch.
5. Lahad Datu Branch.

For simplifying the table, let A - Room Area in (m^2), O – approximate number of occupants in the room, and S – number of SSO design previously for the room. These data are then tabulated as in Table 4 below.

Table 4: The relationship between dimension of room, number of occupants and number of SSO with respect to the room types for some of the bank branches.

	Jinjang			**Tmn Megah**			**TTDI**			**Sime UEP**			**Lahad Datu**		
Room Name	Area (m^2)	Occ. (Qty)	SSO (Qty)	Area (m^2)	Occ. (Qty)	SSO (Qty)	Area (m^2)	Occ. (Qty)	SSO (Qty)	Area (m^2)	Occ. (Qty)	SSO (Qty)	Area (m^2)	Occ. (Qty)	SSO (Qty)
SST	6.23	6	12	8.26	6	18	7.24	6	12	8.23	6	15	10.23	6	18
SST-E	7.48	3	8	8.72	3	12	9.12	3	9	8.65	3	9	12.25	3	9
Banking Hall	30.12	15	24	28.12	15	12	40.12	15	21	41.23	15	26	38.87	15	26
CSO	20.25	5	15	25.63	5	18	22.55	5	18	21.94	5	12	25.10	5	18
Branch Manager	12.13	1	5	16.32	1	5	10.32	1	5	8.80	1	5	12.66	1	5
Back Office	98.12	10	60	94.57	10	42	92.41	10	55	88.98	10	48	96.29	10	52
Pantry	16.65	1	3	17.32	1	3	18.82	1	2	10.77	1	3	9.44	1	3
Server	15.12	1	6	13.22	1	6	12.43	1	6	10.66	1	6	12.44	1	6
Genset	32.44	1	4	20.22	1	3	28.32	1	3	30.14	1	4	26.02	1	4
Surau	15.52	3	2	16.22	3	1	14.24	3	2	13.52	3	2	12.10	3	2
Cashier	40.62	3	12	50.43	3	9	34.65	3	12	38.21	3	14	37.87	3	14

From the above table, we can further analyze the data using the statistical analysis software (SPSS) or EXCEL spreadsheet software to find the Mean, Median, and Average of each room's SSO quantities.

We found out that as the area of the room increases, the number of SSO also increase linearly. Figure 1- 4 below show the behavior of the room size versus the SSO quantities.

Figure 1: A plot of Area, Occupant, and SSO.Quantities versus Room Type for Jinjang Branch.

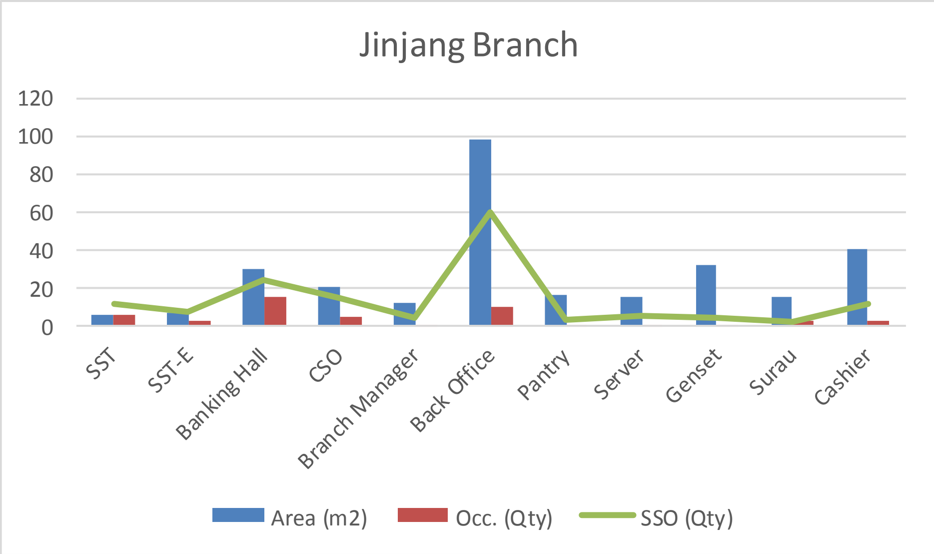


Figure 2: A Plot of Area, Occupant, and SSO.quantities versus Room Type for Taman Megah Branch.

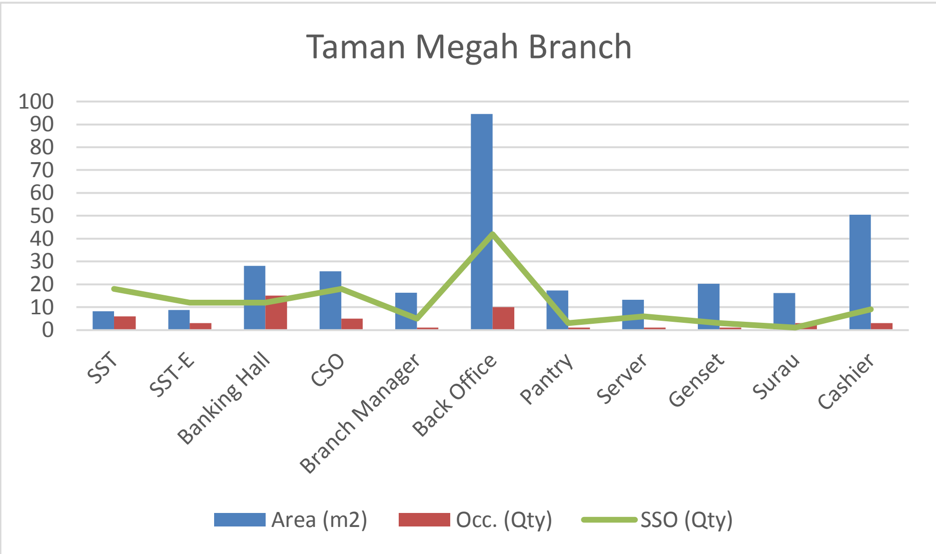


Figure 3: A Plot of Area, Occupant, and SSO.quantities versus Room Type for TTDI Branch.

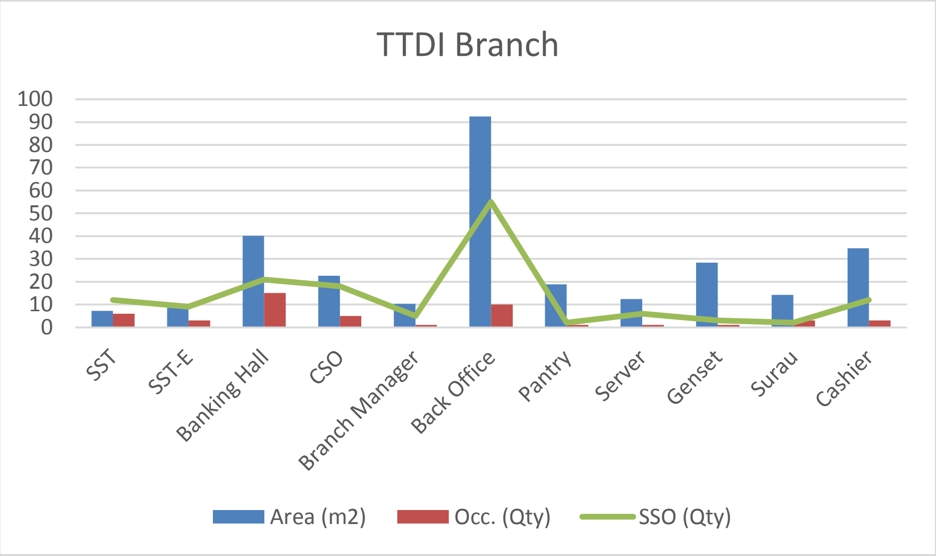


Figure 4: A Plot of Area, Occupant, and SSO.quantities versus Room Type for Sime UEP Branch.

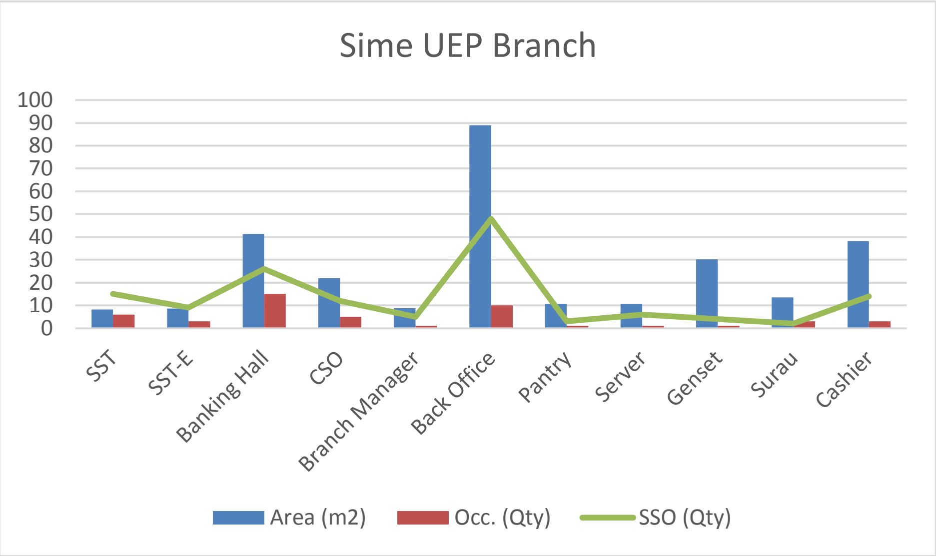
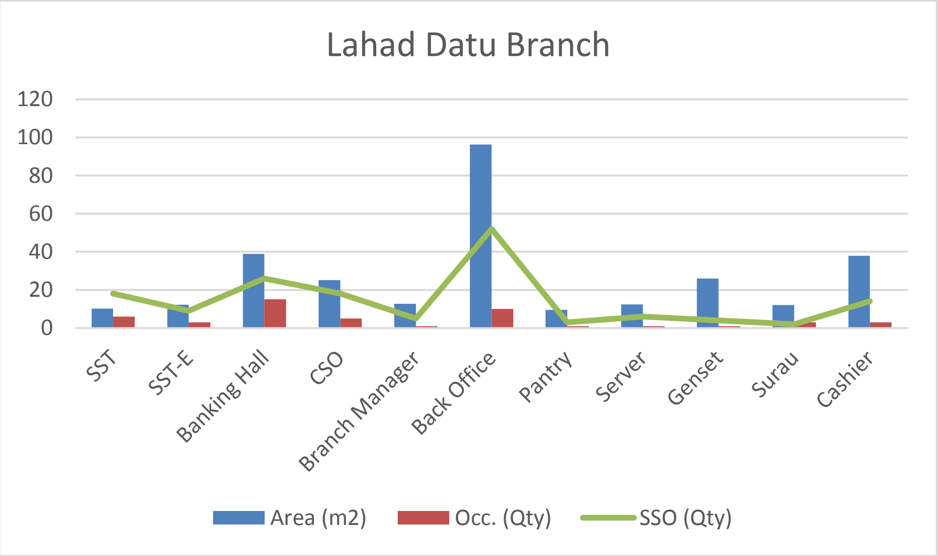


Figure 5: A Plot of Area, Occupant, and SSO.quantities versus Room Type for Lahad Datu

Branch.



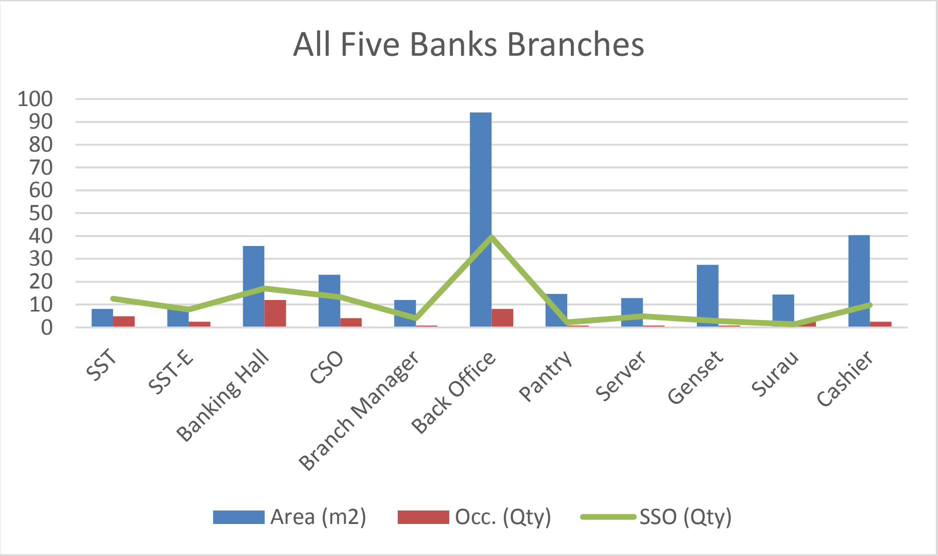
From the above plots, we can see that the SSO quantity increase linearly with the increase of room size. This shows a proportional relationship between these two parameters. The average SSO for the bank's branches are tabulated as in Table 5 as follows:

Table 5: Tabulation of the Area, Occupant, and SSO quantity for comparison.

Room Name	Ave. of Area (m^2)	Ave. of No. of Occupants	Ave. of SSO Quantity
SST	8	5	13
SST-E	9	2	8
Banking Hall	36	12	17
CSO	23	4	13
Branch Manager	12	1	4
Back Office	94	8	39
Pantry	15	1	2
Server	13	1	5
Genset	27	1	3
Surau	14	2	1
Cashier	40	2	10

A plot of graph for the relationship between each objective or parameter is shown as follows:

Figure 6: A plot of Area, Occupant, and SSO quantities versus Room Type for the five bank branches.



This relationship can then be modeled into a mathematical model as mentioned in the following paragraph.

Formulation of Mathematical Models Representing SSO Distributions in a Room

From here, the new diversity factor representing the switch socket outlets requirement in each building will be formulated. This mathematical modeling can then be tested via software simulation to look at the relationship of the model with the existing socket outlets design. In this case, the existing power-layout plans of an electrical low voltage services in building are required to be studied. Few plans representing residential and office buildings will be required for this purpose.

Then, after getting the number of optimized socket outlets from this mathematical model representing the diversity factor, on-site survey will be conducted. This is done to compare the new socket outlets design with the existing through interview with the users of the outlets. The results of this comparison would explain whether the diversity factor's model represent the actual requirement of the users' needs of socket outlets. There might be certain other parameters that could limit the new models of the DF as the time goes by, for example, the new inventions of equipment that might probably be available in the future. This other factor might affect the accuracy of the DF model that leads to the inaccuracy of this model in the future.

CONCLUSION

In conclusion, the research founds out that there exists relationship between room dimensions, number of occupants, and SSO quantities in buildings. The next step is to determine the mathematical models or diversity factors that represent these relationships to ease consulting engineers to design SSO distributions that suit the modern intelligent network requirement with high efficiency functions.

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