# Car Parking Demand Forecasting using Fuzzy Logic

by

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# CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Electrical and Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
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Approved by,

_______________________

(Dr Zuhairi Baharudin)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
Sept 2011

## CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(SOFIA DELAILA BINTI MOHD SAMIN)

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# ABSTRACT

Forecasting in the retail sector can presents some unusual challenge due to special demand pattern. As central business districts, airports, transit stations, and shopping mall continue to become more crowded during peak times, demand for parking spaces has increasing. In this project, Car Parking Demand Forecasting Using Fuzzy Logic will employ the Short-range Demand Forecasting method to predict the future parking spaces demand for Wangsa Walk Mall. The historical data of Wangsa Walk Mall from January 2011 to June 2011 are gathered, analyzed and utilized for the forecasting model's development. A short-range demand forecasting model is developed, simulated and fine-tuning using a mathematical software, *fuzzyTECH*. The proposed model will be tested to forecast car parking demand by weekly with the actual parking data. The most accurate model is obtained by reducing the percentage error between the forecasted and actual value of the parking space demand, in the form of mean absolute percentage error (MAPE) results. This project is expected to develop short-range parking space demand forecasting with mean absolute percentage error (MAPE) lower than 10% for an optimal result and accurate model.

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# CHAPTER 1

# INTRODUCTION

"When King Solomon said there were a time and a place for everything he had not encountered the problem of parking his automobile."

– Bob Edwards (1947-2005)

## 1.1 BACKGROUND

Parking is a key issue in all major cities like New York, Chicago, Seoul, London, Beijing and New Delhi. According to the Ministry of Transport Malaysia (MOT) statistics for the year of 2009 and 2010, there is an increase of approximately 1.2 million passenger vehicles from 19,016,782 to 20,188,565 in Malaysia itself [1]. These 19 million vehicles include cars, motorcycles, buses, taxis, rental cars, and pick-up trucks. The Bloomberg Bussinesweek magazine states that the increases of passenger vehicles that are introduced into the roads each year will ultimately leads to a parking problem due to limited availability of spaces [2]. A customer satisfaction survey conducted by a car manufacturing company, Bavarian Motor Works (BMW) shows that 20% of the inner traffic of major cities across the nation is in search of parking space [3].

Car parking demand forecasting is a critical part for a business district's operation management's function. It has significant influence on achieving optimal operation for the company's parking management. It can predict the future parking demand and estimate the projection of a company's parking capacity. This is important because if the parking capacity is inadequate, the resulting shortages can lead to loss of customers and market interest. This will affect the company's economy, business, loss of time and image. If the demand is over forecasted, it will be a waste of resources as the parking spaces will not be used and wasted [4].

Demand forecasting in operation management is categorized into three forecasting-time-horizon categories which are short-range forecast, medium-range forecast and long-range forecast. Short-range forecast has a time span of up to 1 year but is generally less than 3 months. It is used for capacity, planning purchasing, job scheduling, workforce levels, job assignments and production levels. Meanwhile, medium-range forecasting is usually conducted from three month to three year, and long-range forecasting is normally longer than three year, usually covers from one to ten years ahead [5].

Hence, this project studied the parking space demand pattern by employing the short-range demand forecasting method to predict the future parking spaces demand in Wangsa Walk Mall for 24 consecutive weeks. To achieve this, the Fuzzy Set Theory introduced by Prof. Lotfi A. Zadeh in 1965 was applied as a complement tool to the mathematical approach in solving the parking problems [6].

## 1.2 PROBLEM STATEMENT

### *1.2.1 Problem Identification*

Kuala Lumpur is the second largest populated city in Malaysia and it is the fastest growing metropolitan region in the country. Throughout 2000 to 2010, the average annual population growth rate of Kuala Lumpur grew 1.1% from 1,379,310 to 1,722,500 [7]. The Wangsa Walk Mall, Wangsa Maju is an excellent example of heavy shopper traffic with a pattern of parking inadequacies. Located in Wangsa Maju, Kuala Lumpur the shopping mall is designed as an outdoor walking mall with a total of 173 tenants of high-end outlets.

Frustration will arises because of the wasted time and increasing fuel consumption from going around the parking building just to find an empty parking slot. This scenario happened in any major shopping mall in Malaysia, where hundreds of customers has voice out their concern and dissatisfaction in finding an available parking space upon thousands of parked car. Hence this project can determine a business district's parking capacity and help the retail sector to achieve optimal operation on the parking spaces management.

In order to accurately forecast the short-range car parking demand, important variables such as type of day (such as normal working day, public holiday, special occasion) and type of school day (normal school day or school holiday) must be considered as each of it as a significant effects to the parking demand. All of these variables when combined together can create a large influence in the forecast result.

### *1.2.2 Significance of Project*

The importance of parking demand forecasting shall be emphasized at all levels as the consequences of under or over estimation will affect the company's business. If under estimated, the result would be loss of customers and market interest, thus will affect the economy, business, loss of time and image. If the demand is over forecasted, it will be a waste of resources as the parking spaces will not be used and wasted [4]. Through this project, the company should be able to predict the future parking demand by focusing on fuzzy logic as a technique used in the forecasting method.

## 1.3 OBJECTIVES AND SCOPE OF STUDY

### *1.3.1 Objectives of the Project*

The following objectives were to be achieves from this project:

- To study and analyze the parking space demand in a study area
- To be able to forecast the parking space demand for 7 days ahead and able to revise the forecast based on the input changes.
- To design an accurate Short-ranged Parking Demand Forecasting Model using Fuzzy Logic approach by reducing the percentage error between the forecast and actual value of the parking space occupancy (MAPE).

### *1.3.2 Scope of Study*

Generally, the scope of study will cover the following areas:

- Short-ranged parking demand in Wangsa Walk Mall
- Focus on Fuzzy Logic as a technique that will be used in the forecasting method
- ***fuzzyTECH 5.52*** software as the parking space forecasting tool
- The simulation of short-ranged parking forecasting model

## 1.4 RELEVANCY OF THE PROJECT

Forecasting in the retail sector presents some unusual challenge. A major technique in the retail sector is tracking demand by maintaining good short-term records. Due to special demand pattern, many service firms encounter problems in providing the best service for expectant customers. These special demand patterns should be kept in records, noting not only the day of the week but also unusual events such as public holiday or special occasion, so that pattern that influence demand can be developed [4].

As forecasts is a critical part of the operation management's function, this projects aims to predict the future parking spaces demand in order to determine the total amount of visitors during school/public holidays, normal working day or during the company's special event. Therefore, an accurate prediction for the car parking demand is very important as the consequences of under or over estimation will affect the company's business.

The forecast accuracy; Mean Absolute Percentage Error (MAPE) is measured based on the error statistic of forecast between the models for one week step. The overall MAPE is calculated by taking into calculation each week's MAPE. The lower overall MAPE shows a better accuracy of the forecasting model.

## 1.5 FEASIBILITY OF THE PROJECT

This project will be conducted for two semesters. This includes system research, development and improvement. In this project, the data for parking space occupancy throughout the 24 consecutive weeks were obtained from Wangsa Walk Mall, starting from 03 January 2011 until 19 June 2011 (refer to Appendix A). This project is feasible to be conducted within the time frame and scope.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 BACKGROUND: PARKING LOT DESIGN

Interest in availability of parking lot comes from the problems caused by traffic congestion while trying to find available parking spaces. Traffic congestion has been increasing worldwide as a result of increased motorization, urbanization, population growth, and changes in population density. Congestion reduces efficiency of car parking allocation, and increases travel time, air pollution and fuel consumption. Studies on parking lot must be conducted to collect the required information about the capacity and use of existing parking facilities.

In addition, information about the demand for parking can be obtained. Parking studies will be restricted to a specific study area, such as a central business district. A cordon line is drawn to delineate the study area. It should include traffic generators and a periphery, including all points within an appropriate walking distance. The survey area should also include any area that might be impacted by the parking modifications. The boundary should be drawn to facilitate cordon counts by minimizing the number of entrance and exit points [8].

### *2.1.1 Parking Lot Design and Concep: Accumulation Counts*

It is conducted to obtain data on the number of vehicles parked in a study area during a specific period of time. First, the number of vehicles already in that area are counted or estimated. Then the number of vehicles entering and exiting during that specified period are noted, and added or subtracted from the accumulated number of vehicles. Accumulation data are normally summarized by time period for the entire study area.

The occupancy can be calculated by taking accumulation/total spaces. Peaking characteristics can be determined by graphing the accumulation data by time of day. The accumulation graph usually includes cumulative arrival and cumulative departure graphs as well.

Table 1: Accumulation Table for University of Idaho, United States

**Table 2.** Accumulation Table

| Period | Arrive | Cum. Arr. | Depart | Cum Dep | Accumulation | Accumulation Factor |
|---|---|---|---|---|---|---|
| 4 - 6 AM | 25 | 25 | 5 | 5 | 20 | 0.0341 |
| 6 - 8 | 50 | 75 | 15 | 20 | 55 | 0.0940 |
| 8 - 10 | 250 | 325 | 25 | 45 | 280 | 0.4786 |
| 10 - 12 Noon | 50 | 375 | 30 | 75 | 300 | 0.5128 |
| 12 - 2 PM | 100 | 475 | 50 | 125 | 350 | 0.5982 |
| 2 - 4 | 50 | 525 | 75 | 200 | 325 | 0.5555 |
| 4 - 6 | 25 | 550 | 220 | 420 | 130 | 0.2222 |
| 6 - 8 | 25 | 575 | 100 | 520 | 55 | 0.0940 |
| 8 - 10 | 10 | 585 | 65 | 585 | 0 | 0 |
| Total | 585 | | 585 | | | |

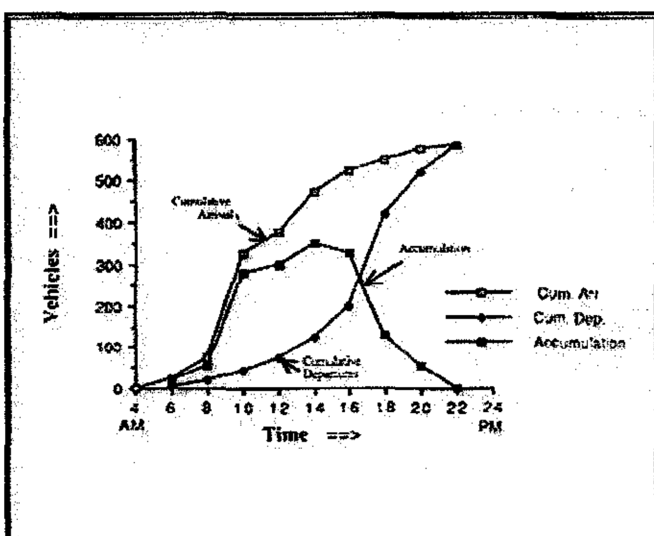



**Figure 2.** Accumulation Diagram

Figure 1: Accumulation Diagram for University of Idaho, United States

## 2.2 FORECASTING TIME HORIZON

Forecasting is the art and science of predicting future events. Forecasting may involve taking historical data and projecting them into the future with some sort of mathematical model. It may be subjective or intuitive prediction. Or it may involve a combination of these – that is, a mathematical model adjusted by a manager's good judgment. Forecasting are seldom, if ever, perfect. They are also costly and time-consuming to prepare and monitor.

A forecast is usually classified by the future time horizon that it covers. Time horizon fall into three categories which are short-range forecast, medium-range forecast and long-range forecast. Short-range forecast has a time span of up to 1 year but is generally less than 3 months. It is used for capacity, planning purchasing, job scheduling, workforce levels, job assignments and production levels. Medium-range forecast, or intermediate, generally spans from 3 months to 3 year. It is useful in sales planning, production planning and budgeting, cash budgeting, and analysis of various operating plan. Long-range forecast, which is generally 3 years or more in time span, are used in planning for new products, capital expenditures, research and development [4].

Short-range forecast tend to be more accurate than longer-range forecast. Factors that influence demand changes every day. Thus, as the time horizon lengthens, it is likely that forecast accuracy will diminish.

Organizations use three major types of forecasts in planning future operations, which are economic forecast, technological forecast and demand forecast. Economic forecasts address the business cycle by predicting inflation rates, money supplies and housing starts, while technological forecast are concerned with rates of technological progress. Demand forecast which is employed in this project are projections of demand for a company's product, goods or services. These forecasts drive a company's production, capacity and scheduling planning systems and serve as inputs to financial, marketing, management decision and personnel planning [9].

## 2.3 FUZZY LOGIC THEORY

### *2.3.1 The Fuzzy Logic Concept*

Natural language abounds with vague and imprecise concepts, such as "Sally is tall," or "It is very hot today." Such statements are difficult to translate into more precise language without losing some of their semantic value: for example, the statement "Sally's height is 152 cm." Does not explicitly state that she is tall, and the statement "Sally's height is 1.2 standard deviations about the mean height for women of her age in her culture" is fraught with difficulties: would a woman 1.1999999 standard deviations above the mean be tall? Which culture does Sally belong to, and how is membership in it defined?

The first publication on fuzzy logic, which also coined its name, dates back to 1965. It was written in the U.S. by Lotfi Zadeh, Professor of Systems Theory at the University of California, Berkeley. From there, the history of fuzzy logic follows the pattern of number recent technologies: invented in the U.S., engineered in Europe, and mass-marketed in Japan [6].

The first industrial applications of fuzzy logic were completed after 1970 in Europe. At Queen Mary College in London, England, Ebrahim Mamdani used fuzzy logic to control a steam generator that he could not get under control with conventional techniques. At the RWTH University of Aachen, Germany, Hans-Jürgen Zimmermann used fuzzy logic for decision support systems. Other industrial applications, such as the control of a cement kiln, followed as a result of this initial work, but fuzzy logic could not get broad acceptance in industry. The few applications that used fuzzy logic hid the fact by circumscribing fuzzy logic with terms such as "multi-valued logic" or "continuous logic."

Fuzzy logic benefits can be seen in its simplicity and its flexibility. Fuzzy logic can handle problems with imprecise and incomplete data, and it can model nonlinear functions of arbitrary complexity [10]. The basic idea of fuzzy logic is simple: in reality, we cannot define a rule for each possible case. Exact rules that cover a case perfectly can only be defined for a few distinct cases. These rules are discrete points in the continuum of possible cases and humans approximate between them.

### *2.3.2 Mathematical Modelling*

Prof. Zadeh contention is that "meaning in natural language is a matter of degree". If we have a proposition such as "Sally is tall", then it is not always possible to assert that it is either true or false. When we know that Sally's height is y, then the "truth", or more correctly, the "compatibility" of y with "is tall", is a matter of degree.

If the proposition is "Sally is under 160cm height" and we know Sally's height, then we can give a yes or no answer to whether the proposition is true or not. In contrast to binary sets that having binary logic (crisp logic), the fuzzy variables may have memberships values of not only 0 or 1. The values can range from 0 to 1. The difference between binary sets and fuzzy logic are as follows:

An ordinary subset A of a set U is determined by its indicator function XA defined by:

$$\text{XA}(x) == \begin{Bmatrix} 1, x \in A \\ 0, x \notin A \end{Bmatrix}$$

Crisp set A is defined by the characteristic function:

$A(x): X \rightarrow 0, 1$

Fuzzy set A is defined by the membership function:

| | | |
|---|---|---|
| $A(x): X \rightarrow [0, 1]$ where: | $A(x) = 1$ | if x is totally in A; |
| | $A(x) = 0$ | if x is not in A; |
| | $0 < A(x) < 1$ | if x is partly in A. |

Or simply,

The previous example shows the fuzzy logic with a numerical value. The fuzzy logic usually is applied for the non numeric linguistic variables. It is often used for facilitating the expression of rules and facts. The Fuzzy Logic uses IF-THEN rules which employ the linguistic variables (fuzzy variables) whose values are in the linguistic terms [10].

The rules are usually expressed in the form of:

**IF** variable **IS** property **THEN** action

| | |
|---|---|
| Rule 1: | IF Distance = medium AND Angle = neg_small THEN Power = pos_high |
| Rule 2: | IF Distance = medium AND Angle = neg_big THEN Power = pos_medium |
| Rule 3: | IF Distance = far AND Angle = neg_small THEN Power = pos_high |

For multiple inputs, the following rule applied:

**If** X **is** A, and Y is B **then** Z is C.

## 2.4 FUZZY LOGIC BASED FORECASTING SYSTEM MODELING

The structure of the fuzzy logic configurations can be represented as below:

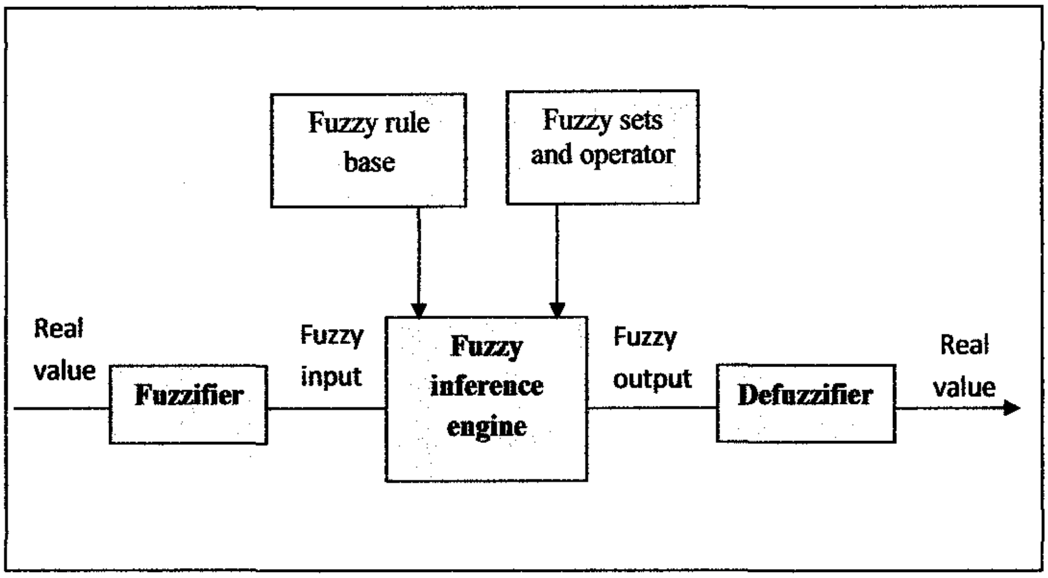



Figure 2: Basic Component of Fuzzy System

### *2.4.1 Fuzzification*

The modelling starts with user entering the inputs. The inputs are in terms of the crisp value. The Fuzzifier will then transforms the real valued input variables into fuzzy values.

### *2.4.2 Fuzzy Inference*

The Fuzzy Inference engine will map the fuzzy inputs earlier to the fuzzy output based on the Fuzzy Rules. The Fuzzy Rules and Fuzzy Set Database are entered by the user to enable the inference engine to function properly. Now that all input variables have been converted to linguistic variable values, the fuzzy inference step can identify the rules that apply to the current situation and compute the value of the output linguistic variable.

The fuzzy inference system is used to evaluate the similarity between the previous forecast days and previous similar days resulting in correction factors, used to correct the similar days of the forecast day to obtain the parking demand forecast. The computation of the fuzzy inference consists of three components:

- Aggregation:

Computation of the IF part of the rules. This step computes the support of the rule relative to the conditions.

- Composition:

Computation of the THEN part of the rules. This step computes the degree of truth for the rule.

- Result Aggregation:

After the degrees of truth for the rules are computed, this step determines which rules will contribute to the Defuzzified result

Rule base optimization often consists of arbitrary rule addition/deletion. This method can result in a clumsy trial-and-error approach as the individual importance of a rule can be expressed only as a 0 or 1.

For this reason, most *fuzzyTECH* Editions support an advanced inference method, the Fuzzy Associative Maps inference, or FAM. With FAM, each rule is assigned a degree of support representing the individual importance of the rule. Rules themselves can be "fuzzy" – meaning, with validity between 0 and 1.

The validity of a conclusion is calculated by a linking of the validity of the entire condition with the degree of support by a composition operator. When the product operator is used as the composition operator, the degree of support reflects rule "significance" [6].

### *2.4.3 Defuzzification*

The result produced from the evaluation of fuzzy rules is fuzzy. Membership functions are used to retranslate the fuzzy output into a crisp value. This translation is known as Defuzzification and can be performed using several methods. Thus, the result of the fuzzy inference is retranslated from a linguistic concept to a crisp output value.

## 2.5 IMPORTANT FACTORS FOR PARKING SPACE DEMAND FORECAST

Generally, there are several factors that may affect the parking space demand forecasting result. Based on the scope of location whereby this project was conducted, which is Wangsa Walk Mall, the following input variables have been taken into account:

### *2.5.1 School type*

The influence of geographical location of Wangsa Walk Mall which is located near several schools around Wangsa Maju and Setapak are one of the determining factors in parking space demand forecasting. There are 43 schools in three kilometre perimeter such as Seri Utama Private School, Kolej Tunku Abdul Rahman, SK/SMK Padang Tembak, SK/SMK Desa Tun Hussein Onn, SK Polis Depot, SK/SMK Taman Setiawangsa, Consist College, SK/SMK Setapak Indah, SK/SMK Wangsa Melawati, SK/SMK Danau Kota, SK/SMK Lembah Keramat, Institute Media Icon, CECE Institute, SK/SMK Wangsa Jaya, Malaysian Institute of Art (MIA), SK/SMK Air Panas, SK Marian Convent, SK/SMK Taman Seri Rampai, SMK Wangsa Maju Seksyen 5 and SMK Zon R1 Wangsa Maju. Parking demand will rises when the school holidays are on and drops during school normal day. Thus, it is necessary to include the type of school day; on and off as the input.

Input Variable: School Type

| | |
|---|---|
| School Holiday | 1 |
| School Day | 2 |

The map in Figure 5 shows the location of the Wangsa Walk Mall with the surrounding schools in three kilometre perimeter below:


Figure 3: Wangsa Walk Mall Location

### *2.5.2 Day type*

There are significance differences in parking space occupancy between weekdays and weekend. Parking space demand on different weekdays in the same may behave differently. The type of the day can be classified into three class; public holiday, normal working day and special event that are conducted by the shopping mall. During public holiday, the normal parking occupancy rises drastically, while during special occasion, the demand rise as significant as the public holidays.

Special events that are conducted at Wangsa Walk Mall for the past six months between 3 January 2011 and 19 June 2011 are Superstar Karaoke Season 2 @WangsaWalk, Crime Prevention Awareness Day, Fun Chess Move@WWM, 1Malaysia Mega Sales and Chinese New Year Sales. These events attracted thousands of visitors around the Federal Territory of Kuala Lumpur where parking demand will rises drastically which up to the point the parking spaces could not occupy all the expected visitors.

The mall is also participating in 1Malaysia Mega Sale Carnival 2011 (1MMSC) by the Tourism Malaysia. The 1Malaysia Unified Sale offers consumers discounts, incentives and added services throughout all sectors of the economy. Among the sectors that are participating in the Malaysia Unified Sale are retail, food and beverage, hotel, tourist attraction, electronic and electrical. Tourism Malaysia is also adding more excitement to the sale carnival with its Shopping Voucher programme which offers discounts and special sale promotions from various retailers nationwide. This special event has engrossed RM56.5 billion nationwide and from this amount, RM16.2 million was contributed by the shopping sector [11]. Sales and discount promotion has attracted visitors especially during festive season and shopping for the first school of day.

On weekends, the shopping mall will be crowded with people from all walks of life as it is very popular among youngsters as well as families. On weekdays, especially on Wednesday when it is the 'movie day' for TGV Cinemas, visitors will be queuing up for the theatres as all movies will be discounted for the whole day. Hence, it is expected for the increase of parking space demand on Wednesday. An article made by Mandy Barrow, the Britons has made 123 million visits to the cinema in 1998 making it the most popular cultural activity in the UK. In the first half of 2011, the number of people going out for a movie has increased by 17.9% [12].

A survey conducted by Dr Lorrin Koram, a researcher from Stanford University, it is found that one in 20 adults spend their time on Saturday to shop. According to Dr Koram, some women and men has even suffered from compulsive shopping and the disorder continued from the habits of going to shopping mall to shop every Saturday [13].

He also states that compulsive buying is nevertheless a good opportunity for the shopping sector to gain their profits, however it is crucial for the study on human's behaviour and how it can contribute to other aspect. Hence, this finding shows that these shoppers are contributing the numbers of visitors on Saturday and any other day.

Since 2001, eating out has grown in popularity as growing wealth, increasing discretionary spend and a number of social factors have all contributed to the growth in the eating out market. These social factors is particularly the increase in the proportion of working women, the growth in less-traditional family structures and the increase in single households [14]. With great varieties of dining restaurants, eating out has becoming a trend for a handful number of families, as it can be seen every day and every night in Wangsa Walk Mall.

During weekends, it is also the time for families to spend their quality time together. Often the parents are not at home, having to work a five day week from Monday to Friday. This will ultimately lead to the rise on parking demands especially on Saturday and Sunday, if not, on nights of weekdays.

Input Variable: Day Type

| | |
|---|---|
| Public Holiday | 1 |
| Normal Day | 2 |
| Special Occasion | 3 |

Special Occasion: Sale, Public Event, Celebrity Appearance, Company Event

### *2.5.3 Parking Space Demand in Wangsa Walk Mall*

The total parking space demand fluctuates depending on the day of the week. Studies on the parking space demand behaviour are required as to understand why certain number is rising and others decreasing.

The table below shows the summary of the minimum and maximum of parking space demand along with the average parking space occupancy on Monday until Friday for the whole 24 weeks (refer Appendix B for details).

Table 2: Parking Space Occupancy Summary

| | **Minimum** | | **Maximum** | | **Average** |
|---|---|---|---|---|---|
| | **School Day** | **School Holiday** | **School Day** | **School Holiday** | |
| **Monday** | 357 | 544 | 692 | 702 | 574 |
| **Tuesday** | 375 | 556 | 552 | 593 | 519 |
| **Wednesday** | 502 | 574 | 602 | 593 | 568 |
| **Thursday** | 400 | 431 | 536 | 583 | 489 |
| **Friday** | 459 | 563 | 599 | 664 | 571 |
| **Saturday** | 616 | 660 | 710 | 709 | 674 |
| **Sunday** | 625 | 533 | 710 | 708 | 644 |

The highest average parking space occupancy was recorded on Saturday and the lowest was on Thursday. The example of parking space occupancy during school day and school holiday are shown in the next graphs.

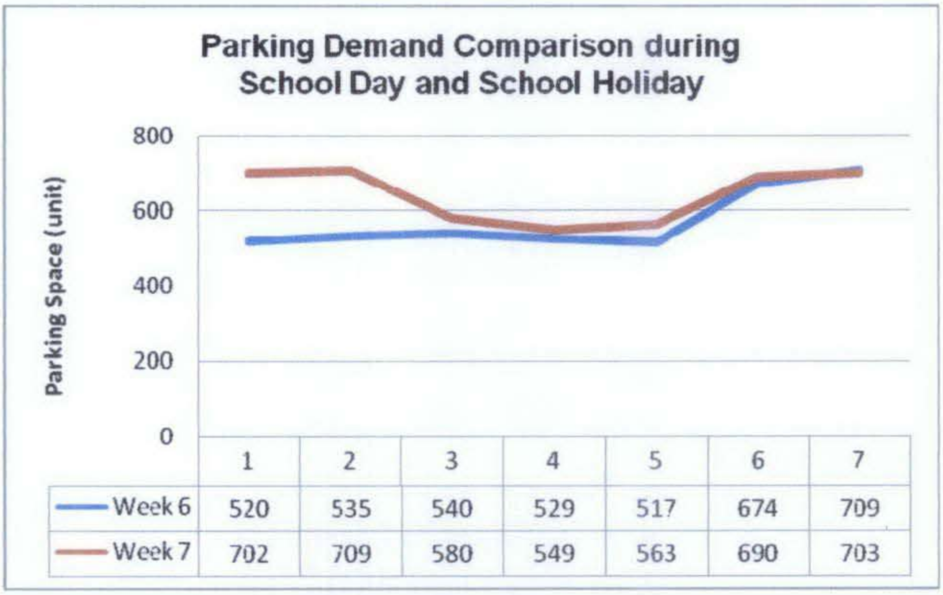



Figure 4: Parking Demand Comparison during School Day and School Holiday

The graph above shows the typical parking space occupancy on 2 consecutive weeks. The normal school day occurs on week 6 and the Chinese New Year holiday occurs in week 7, showing significance increase in the parking demand. From the same graph, it is noticed that the parking space demand on a particular weekday is not largely differs from the day before. However, the demands during weekend were rose drastically.

During week 7 on Wednesday, there are significance drop for parking demand compared to the day before, Monday and Tuesday which is the day of Chinese New Year. It is public holiday for both parents and their children; hence the parking demand for that day is very high. Then, the adults are back to work on Wednesday which ultimately the demand for parking is dropping. However, the number is quiet high compared to other normal day.

# CHAPTER 3

# METHODOLOGY

## RESEARCH METHODOLOGY

This chapter will discuss the detail explanation of methodology that is applied in order to finish the project. This project is divided into a few steps to make sure it flows smoothly.

## 3.1 PROCEDURE IDENTIFICATION

In order to create the forecasting model, the historical Wangsa Walk Mall daily parking data have been gathered ranging from 3rd January 2011 until 19th June 2011 and further categorized into several types. Then, the input variables which are day type (public holiday, normal working day and special occasion) and school day type (school day and school holiday), and output variables (forecasted parking spaces) were defined. From the data obtained, the trending for parking spaces occupancy are analyzed and grouped into different range.

From the study, the membership functions were established. The membership function of a fuzzy set is a generalization of the indicator function in classical sets. In fuzzy logic, membership function represents the degree of truth as an extension of valuation [15]. The next part is the construction of the Fuzzy IF-THEN Rule Blocks for each forecast output.

During simulation, the forecast output shall be compared with the real parking spaces occupancy of that particular day in order to test the system accuracy. The flow chart in Figure 7 explains the methodology of overall modelling process using *fuzzyTECH* software.

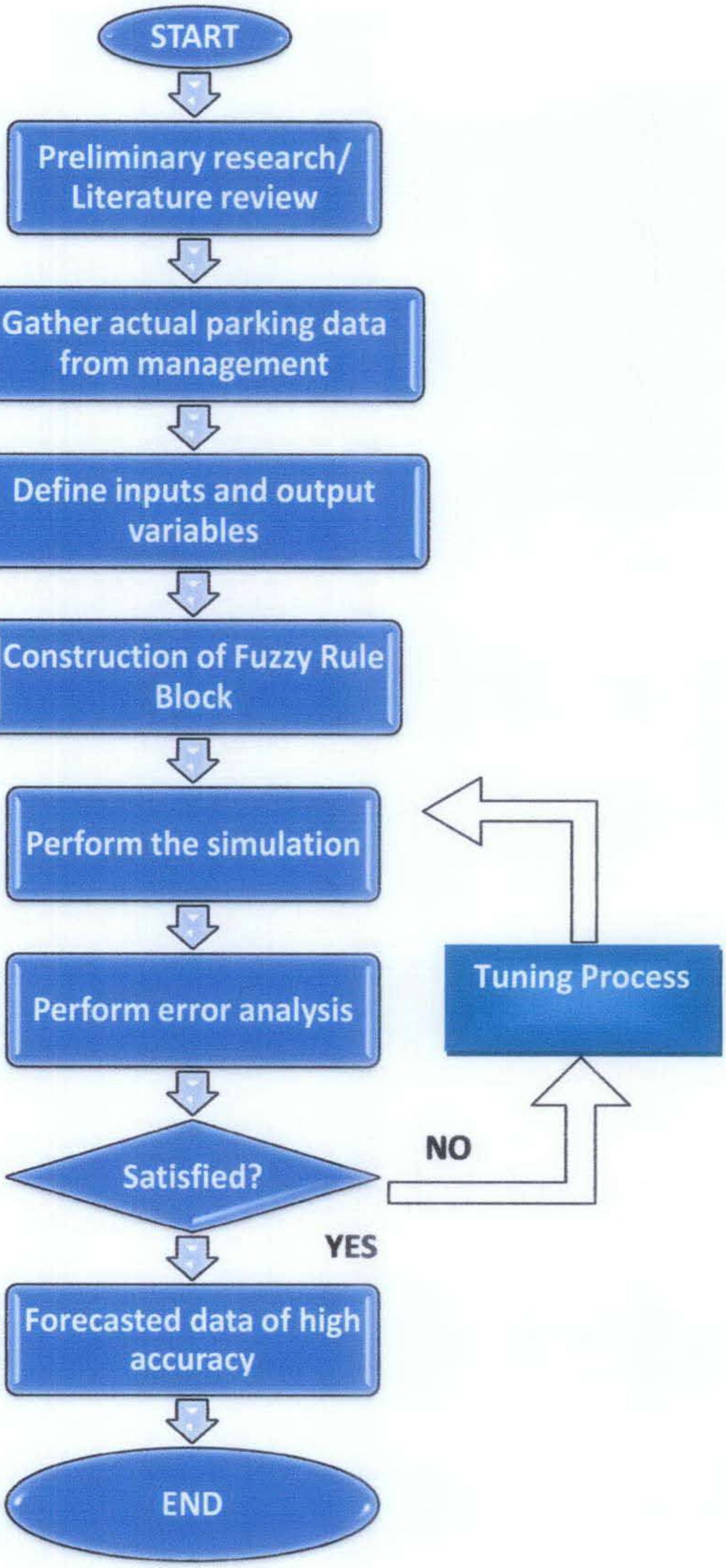



Figure 5: Flowchart for System Design Approach

## 3.2 SYSTEM DESIGN

The current existing model was developed by using the method shown in Figure 8. Performing error analysis will determine the system accuracy. As the overall mean absolute percentage error (MAPE) for the system was higher than 10%, the process of fine-tuning must be performed to refined the system accuracy.

## 3.3 ERROR CALCULATION

In order to evaluate the efficiency of the forecast, the performance criteria would be introduced and investigated. The forecast accuracy; Mean Absolute Percentage Error (MAPE) is measured based on the error statistic of forecast between the models for one week step.

The overall MAPE is calculated by taking into calculation each week's MAPE. The lower overall MAPE shows a better accuracy of the forecasting model. The MAPE is computed in terms of weekly MAPE. The MAPE calculation when school day and school holiday can be calculated as follows:

$$\%\,Absolute\ error = \frac{|Actual\ parking - \ Forecast\ parking|}{Actual\ parking}\ x\ 100\%$$

$$MAPE = \frac{1}{N}\sum_{i=1}^{N}\left|\frac{P_A^i - P_F^i}{P_A^i}\right| X\ 100\%$$

Where PA is actual parking, PF is the forecasted parking and N is the number of data points.

## 3.4 PROCESS FINE TUNING

If the forecasted result shows high MAPE, then a process called fine tuning needed to be done. The fine tuning process is a trial and error process, that is repeated during simulation until an optimal result or an accurate model is obtained. The fine tuning involves the process of specifying and editing the IF-THEN rules as well as the Degree of Support (DoS) for the rules.

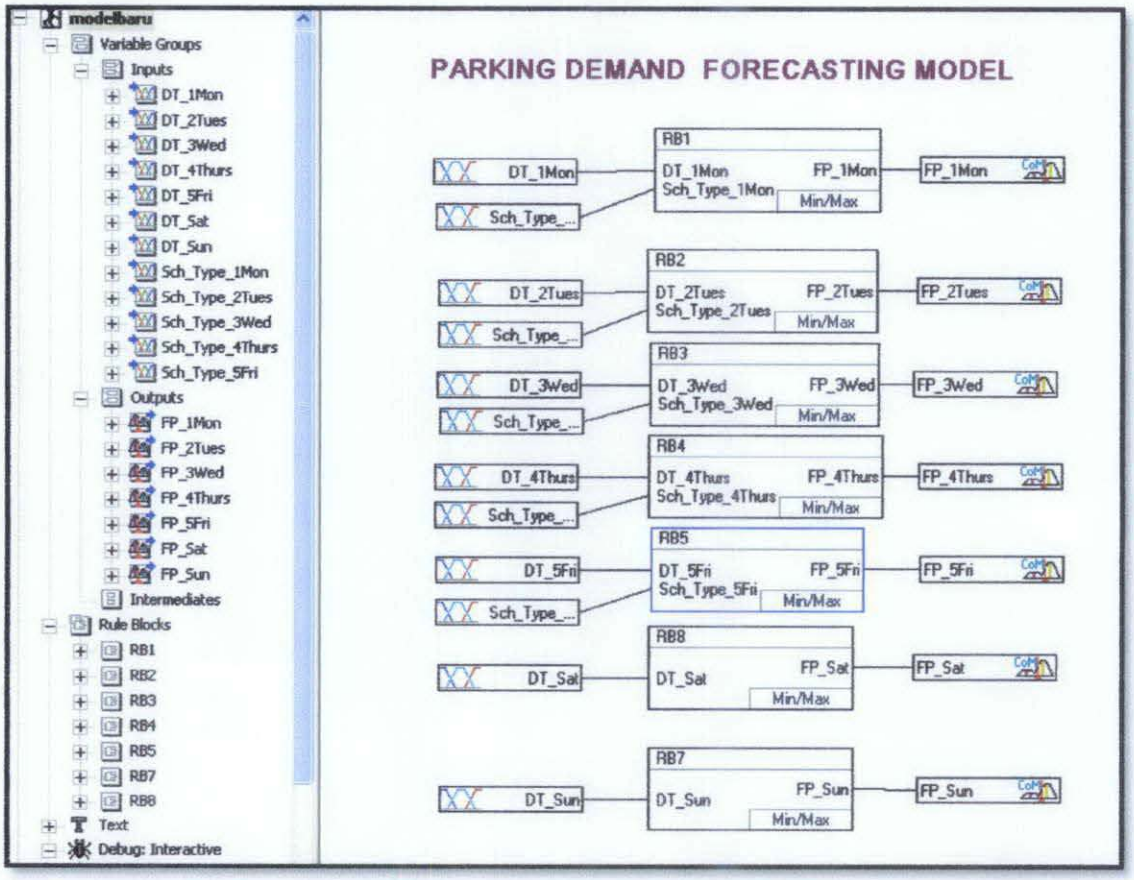



Figure 6: Forecasting Model Project Editor

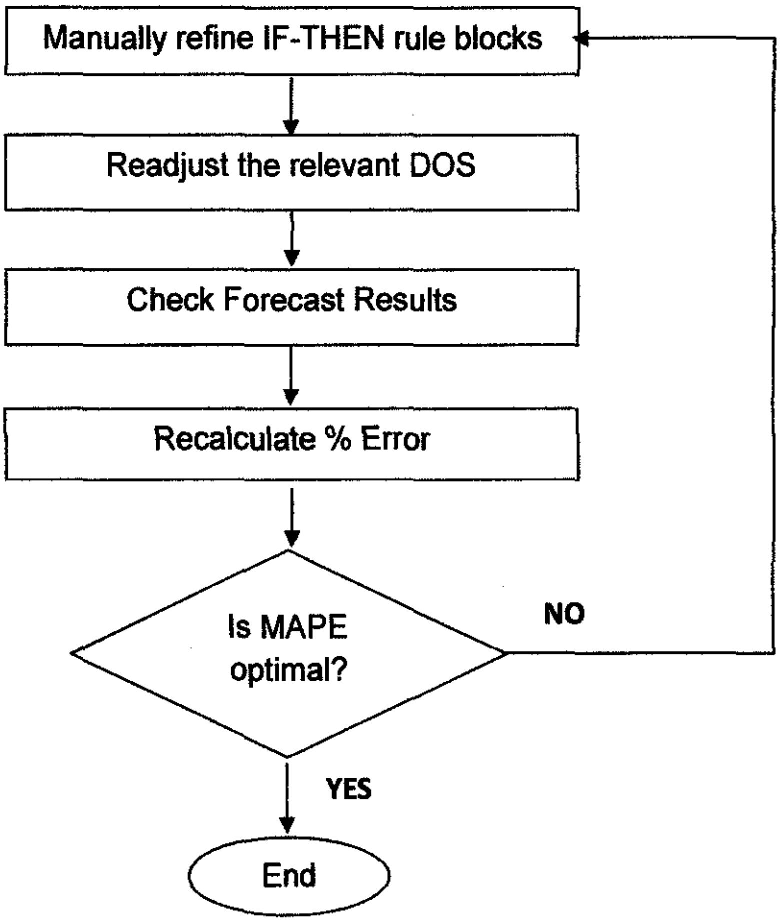
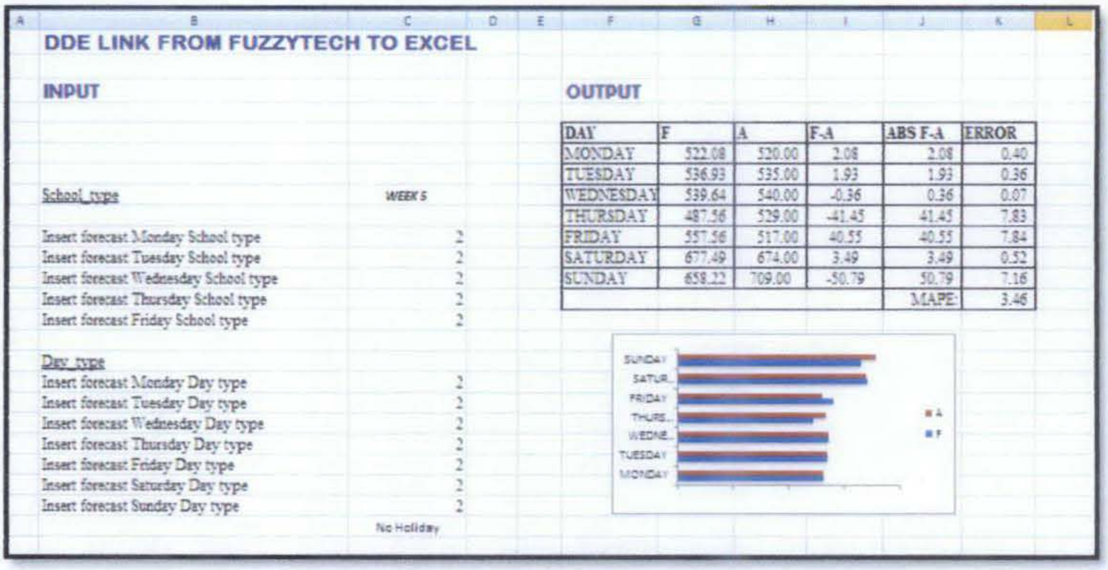



Figure 7: Process of Fine Tuning

First of all, the number of rules in each block, and the configuration the rule were maintained. The manual adjustment will be started from the first rule block, which is the rule block for forecast Monday. In this process, all 24 weeks will be run one by one. In every week that was run, to which rules (in rule block Monday) it was related to will be noted and recorded.

After all the 24 weeks data has been gathered, weeks that may be sharing the same rules are grouped. By doing this, we now know which rules are affected the particular weeks output. Then, adjustment can be made to the Degree of Support of the respective rules, so that the percentage error between forecast value and actual parking demand value on Monday is optimal minimum and balance. The same action was repeated for Tuesday, Wednesday, Thursday, Friday, Saturday and Sunday.




| DAY | F | A | F-A | ABS F-A | ERROR |
|---|---|---|---|---|---|
| MONDAY | 522.08 | 520.00 | 2.08 | 2.08 | 0.40 |
| TUESDAY | 536.93 | 535.00 | 1.93 | 1.93 | 0.36 |
| WEDNESDAY | 539.64 | 540.00 | -0.36 | 0.36 | 0.07 |
| THURSDAY | 487.56 | 529.00 | -41.45 | 41.45 | 7.83 |
| FRIDAY | 557.56 | 517.00 | 40.55 | 40.55 | 7.84 |
| SATURDAY | 677.49 | 674.00 | 3.49 | 3.49 | 0.52 |
| SUNDAY | 658.22 | 709.00 | -50.79 | 50.79 | 7.16 |
| | | | | MAPE: | 3.46 |

Figure 8: Input Data for Monday, Week 6

## 3.5 TOOLS

The tools required for this project are ***fuzzyTECH*** **5.52** Professional Edition Software and Microsoft Excel.

### 3.6 GANTT CHART

Table 3: Gantt chart for FYP 1

| No. | Detail/Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Selection of Project Topic | ■ | ■ | | | | | | MID SEMESTER BREAK | | | | | | | |
| 2. | Preliminary Research Work | | ■ | ■ | ■ | ■ | | | | | | | | | | |
| 3. | Submission of Extended Proposal Defence | | | | | | ● | | | | | | | | | |
| 4. | Proposal Defence | | | | | | | ■ | | ■ | ■ | | | | | |
| 5. | Experimental Setup to Test the Sensors | | | | | | | | | | | ■ | ■ | ■ | | |
| 6. | Submission of Interim Draft Report | | | | | | | | | | | | | | ● | |
| 7. | Submission of Interim Report | | | | | | | | | | | | | | | ● |

● Suggested Milestone ■ Process

Table 4: Gantt chart for FYP 2

| No. | Detail/Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Project Work | | | | | | | | MID SEMESTER BREAK | | | | | | | | |
| 2. | Model improvement (Fine Tuning) | | | | | | | | | | | | | | | | |
| 3. | Submission of Progress Report | | | | | | | | | | | | | | | | |
| 4. | Project work continue | | | | | | | | | | | | | | | | |
| 5. | Poster Exhibition | | | | | | | | | | | | | | | | |
| 6. | Submission of Dissertation Report (softcopy) | | | | | | | | | | | | | | | | |
| 7. | Submission of Technical Paper | | | | | | | | | | | | | | | | |
| 8. | Viva | | | | | | | | | | | | | | | | |
| 9 | Submission of Project Dissertation (Hard Bound) | | | | | | | | | | | | | | | | |

Suggested Milestone    Process

# CHAPTER 4

# RESULT & DISCUSSION

## 4.1 NEW RULE BLOCK

| # | IF | | THEN | |
|---|---|---|---|---|
| | DT_1Mon | Sch_Type_1Mon | DoS | FP_1Mon |
| 1 | public | Sch_Off | 0.10 | very_low |
| 2 | public | Sch_Off | 0.10 | low |
| 3 | public | Sch_Off | 0.10 | medium |
| 4 | public | Sch_Off | 0.30 | high |
| 5 | public | Sch_Off | 0.10 | very_high |
| 6 | public | Sch_On | 1.00 | very_low |
| 7 | public | Sch_On | 1.00 | low |
| 8 | public | Sch_On | 1.00 | medium |
| 9 | public | Sch_On | 1.00 | high |
| 10 | public | Sch_On | 1.00 | very_high |
| 11 | normal | Sch_Off | 0.40 | very_low |
| 12 | normal | Sch_Off | 0.30 | low |
| 13 | normal | Sch_Off | 1.00 | medium |
| 14 | normal | Sch_Off | 1.00 | high |
| 15 | normal | Sch_Off | 1.00 | very_high |
| 16 | normal | Sch_On | 1.00 | very_low |
| 17 | normal | Sch_On | 1.00 | low |
| 18 | normal | Sch_On | 1.00 | medium |
| 19 | normal | Sch_On | 1.00 | high |
| 20 | normal | Sch_On | 1.00 | very_high |
| 21 | special | Sch_Off | 1.00 | very_low |
| 22 | special | Sch_Off | 1.00 | low |
| 23 | special | Sch_Off | 1.00 | medium |
| 24 | special | Sch_Off | 1.00 | high |
| 25 | special | Sch_Off | 1.00 | very_high |
| 26 | special | Sch_On | 1.00 | very_low |
| 27 | special | Sch_On | 1.00 | low |
| 28 | special | Sch_On | 1.00 | medium |
| 29 | special | Sch_On | 1.00 | high |
| 30 | special | Sch_On | 1.00 | very_high |

Figure 9: Rule Block Monday

| # | IF |  | THEN |  |
|---|---|---|---|---|
|  | DT_2Tues | Sch_Type_2Tues | DoS | FP_2Tues |
| 1 | public | Sch_Off | 0.10 | very_low |
| 2 | public | Sch_Off | 0.20 | low |
| 3 | public | Sch_Off | 0.10 | medium |
| 4 | public | Sch_Off | 1.00 | high |
| 5 | public | Sch_Off | 1.00 | very_high |
| 6 | public | Sch_On | 1.00 | very_low |
| 7 | public | Sch_On | 1.00 | low |
| 8 | public | Sch_On | 1.00 | medium |
| 9 | public | Sch_On | 1.00 | high |
| 10 | public | Sch_On | 1.00 | very_high |
| 11 | normal | Sch_Off | 0.10 | very_low |
| 12 | normal | Sch_Off | 0.20 | low |
| 13 | normal | Sch_Off | 0.10 | medium |
| 14 | normal | Sch_Off | 1.00 | high |
| 15 | normal | Sch_Off | 1.00 | very_high |
| 16 | normal | Sch_On | 1.00 | very_low |
| 17 | normal | Sch_On | 1.00 | low |
| 18 | normal | Sch_On | 1.00 | medium |
| 19 | normal | Sch_On | 1.00 | high |
| 20 | normal | Sch_On | 1.00 | very_high |
| 21 | special | Sch_Off | 1.00 | very_low |
| 22 | special | Sch_Off | 1.00 | low |
| 23 | special | Sch_Off | 1.00 | medium |
| 24 | special | Sch_Off | 1.00 | high |
| 25 | special | Sch_Off | 1.00 | very_high |
| 26 | special | Sch_On | 1.00 | very_low |
| 27 | special | Sch_On | 1.00 | low |
| 28 | special | Sch_On | 1.00 | medium |
| 29 | special | Sch_On | 1.00 | high |
| 30 | special | Sch_On | 1.00 | very_high |

Figure 10: Rule Block Tuesday

| # | IF | | THEN | |
|---|---|---|---|---|
| | DT_3Wed | Sch_Type_3Wed | DoS | FP_3Wed |
| 1 | public | Sch_Off | 1.00 | very_low |
| 2 | public | Sch_Off | 1.00 | low |
| 3 | public | Sch_Off | 1.00 | medium |
| 4 | public | Sch_Off | 1.00 | high |
| 5 | public | Sch_Off | 1.00 | very_high |
| 6 | public | Sch_On | 1.00 | very_low |
| 7 | public | Sch_On | 1.00 | low |
| 8 | public | Sch_On | 1.00 | medium |
| 9 | public | Sch_On | 1.00 | high |
| 10 | public | Sch_On | 1.00 | very_high |
| 11 | normal | Sch_Off | 0.10 | very_low |
| 12 | normal | Sch_Off | 0.10 | low |
| 13 | normal | Sch_Off | 0.40 | medium |
| 14 | normal | Sch_Off | 1.00 | high |
| 15 | normal | Sch_Off | 1.00 | very_high |
| 16 | normal | Sch_On | 1.00 | very_low |
| 17 | normal | Sch_On | 1.00 | low |
| 18 | normal | Sch_On | 1.00 | medium |
| 19 | normal | Sch_On | 1.00 | high |
| 20 | normal | Sch_On | 1.00 | very_high |
| 21 | special | Sch_Off | 1.00 | very_low |
| 22 | special | Sch_Off | 1.00 | low |
| 23 | special | Sch_Off | 1.00 | medium |
| 24 | special | Sch_Off | 1.00 | high |
| 25 | special | Sch_Off | 1.00 | very_high |
| 26 | special | Sch_On | 1.00 | very_low |
| 27 | special | Sch_On | 1.00 | low |
| 28 | special | Sch_On | 1.00 | medium |
| 29 | special | Sch_On | 1.00 | high |
| 30 | special | Sch_On | 1.00 | very_high |

Figure 11: Rule Block Wednesday

| # | IF | | THEN | |
|---|---|---|---|---|
| | DT_4Thurs | Sch_Type_4Thurs | DoS | FP_4Thurs |
| 1 | public | Sch_off | 1.00 | very_low |
| 2 | public | Sch_off | 1.00 | low |
| 3 | public | Sch_off | 1.00 | medium |
| 4 | public | Sch_off | 1.00 | high |
| 5 | public | Sch_off | 1.00 | very_high |
| 6 | public | Sch_On | 1.00 | very_low |
| 7 | public | Sch_On | 1.00 | low |
| 8 | public | Sch_On | 1.00 | medium |
| 9 | public | Sch_On | 1.00 | high |
| 10 | public | Sch_On | 1.00 | very_high |
| 11 | normal | Sch_off | 1.00 | very_low |
| 12 | normal | Sch_off | 0.60 | low |
| 13 | normal | Sch_off | 0.10 | medium |
| 14 | normal | Sch_off | 0.10 | high |
| 15 | normal | Sch_off | 0.10 | very_high |
| 16 | normal | Sch_On | 1.00 | very_low |
| 17 | normal | Sch_On | 1.00 | low |
| 18 | normal | Sch_On | 1.00 | medium |
| 19 | normal | Sch_On | 1.00 | high |
| 20 | normal | Sch_On | 1.00 | very_high |
| 21 | special | Sch_off | 1.00 | very_low |
| 22 | special | Sch_off | 1.00 | low |
| 23 | special | Sch_off | 0.70 | medium |
| 24 | special | Sch_off | 0.10 | high |
| 25 | special | Sch_off | 0.20 | very_high |
| 26 | special | Sch_On | 1.00 | very_low |
| 27 | special | Sch_On | 1.00 | low |
| 28 | special | Sch_On | 1.00 | medium |
| 29 | special | Sch_On | 1.00 | high |
| 30 | special | Sch_On | 1.00 | very_high |

Figure 12: Rule Block Thursday

| # | IF<br>DT_5Fri | Sch_Type_5Fri | THEN<br>DoS | FP_5Fri |
|---|---|---|---|---|
| 1 | public | Sch_Off | 1.00 | very_low |
| 2 | public | Sch_Off | 1.00 | low |
| 3 | public | Sch_Off | 1.00 | medium |
| 4 | public | Sch_Off | 1.00 | high |
| 5 | public | Sch_Off | 1.00 | very_high |
| 6 | public | Sch_On | 1.00 | very_low |
| 7 | public | Sch_On | 1.00 | low |
| 8 | public | Sch_On | 1.00 | medium |
| 9 | public | Sch_On | 1.00 | high |
| 10 | public | Sch_On | 1.00 | very_high |
| 11 | normal | Sch_Off | 1.00 | very_low |
| 12 | normal | Sch_Off | 1.00 | low |
| 13 | normal | Sch_Off | 1.00 | medium |
| 14 | normal | Sch_Off | 1.00 | high |
| 15 | normal | Sch_Off | 1.00 | very_high |
| 16 | normal | Sch_On | 1.00 | very_low |
| 17 | normal | Sch_On | 1.00 | low |
| 18 | normal | Sch_On | 1.00 | medium |
| 19 | normal | Sch_On | 1.00 | high |
| 20 | normal | Sch_On | 1.00 | very_high |
| 21 | special | Sch_Off | 1.00 | very_low |
| 22 | special | Sch_Off | 1.00 | low |
| 23 | special | Sch_Off | 1.00 | medium |
| 24 | special | Sch_Off | 1.00 | high |
| 25 | special | Sch_Off | 1.00 | very_high |
| 26 | special | Sch_On | 1.00 | very_low |
| 27 | special | Sch_On | 1.00 | low |
| 28 | special | Sch_On | 1.00 | medium |
| 29 | special | Sch_On | 1.00 | high |
| 30 | special | Sch_On | 1.00 | very_high |

Figure 13: Rule Block Friday

| # | IF | THEN | |
|---|---|---|---|
| | DT_Sat | DoS | FP_Sat |
| 1 | public | 1.00 | very_low |
| 2 | public | 1.00 | low |
| 3 | public | 1.00 | medium |
| 4 | public | 1.00 | high |
| 5 | public | 1.00 | very_high |
| 6 | normal | 0.10 | very_low |
| 7 | normal | 0.10 | low |
| 8 | normal | 0.40 | medium |
| 9 | normal | 0.80 | high |
| 10 | normal | 1.00 | very_high |
| 11 | special | 1.00 | very_low |
| 12 | special | 1.00 | low |
| 13 | special | 1.00 | medium |
| 14 | special | 1.00 | high |
| 15 | special | 1.00 | very_high |

Figure 14: Rule Block Saturday

| # | IF | THEN | |
|---|---|---|---|
| | DT_Sun | DoS | FP_Sun |
| 1 | public | 1.00 | very_low |
| 2 | public | 1.00 | low |
| 3 | public | 1.00 | medium |
| 4 | public | 1.00 | high |
| 5 | public | 1.00 | very_high |
| 6 | normal | 0.10 | very_low |
| 7 | normal | 0.10 | low |
| 8 | normal | 0.10 | medium |
| 9 | normal | 1.00 | high |
| 10 | normal | 1.00 | very_high |
| 11 | special | 1.00 | very_low |
| 12 | special | 1.00 | low |
| 13 | special | 1.00 | medium |
| 14 | special | 1.00 | high |
| 15 | special | 1.00 | very_high |
| 16 | | | |

Figure 15: Rule Block Sunday

## 4.2 SIMULATION RESULT

The process of transferring data from fuzzyTECH to an excel file are called Dynamic Data Exchange (DDE). fuzzyTECH will run and the forecasted output result will be presented in the excel file. All calculations are performed in the table below:

Table 5: MAPE Calculation in Excel for Week 6

| DAY | F | A | F-A | ABS F-A | ERROR |
|---|---|---|---|---|---|
| MONDAY | 522.08 | 520.00 | 2.08 | 2.08 | 0.40 |
| TUESDAY | 536.93 | 535.00 | 1.93 | 1.93 | 0.36 |
| WEDNESDAY | 539.64 | 540.00 | -0.36 | 0.36 | 0.07 |
| THURSDAY | 487.56 | 529.00 | -41.45 | 41.45 | 7.83 |
| FRIDAY | 557.56 | 517.00 | 40.55 | 40.55 | 7.84 |
| SATURDAY | 677.49 | 674.00 | 3.49 | 3.49 | 0.52 |
| SUNDAY | 658.22 | 709.00 | -50.79 | 50.79 | 7.16 |
| | | | | MAPE: | 3.46 |

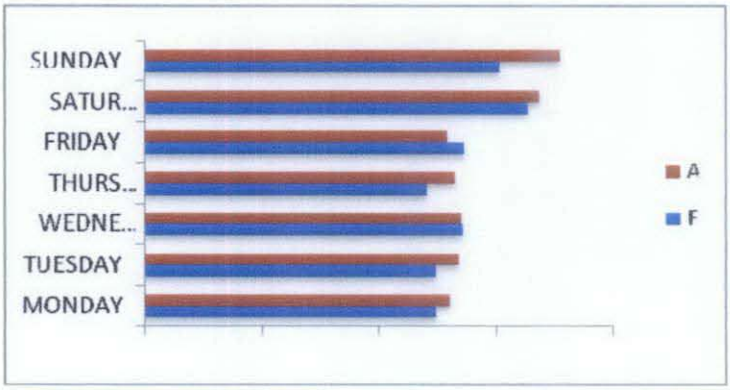



Figure 16: Graph Actual Vs Forecast for Week 6

MAPE values of each school type for the forecast model are shown in Table 6,7 and 8 below:

Table 6: MAPE during School Day

| Week | MAPE Value (%) |
|---|---|
| 1 | 7.50 |
| 2 | 11.49 |
| 3 | 12.41 |
| 4 | 8.43 |
| 5 | 5.61 |
| 6 | 3.46 |
| 8 | 6.33 |
| 9 | 5.88 |
| 10 | 5.73 |
| 12 | 11.82 |
| 13 | 8.36 |
| 14 | 9.47 |
| 15 | 7.32 |
| 16 | 11.56 |
| 17 | 7.88 |
| 18 | 10.89 |
| 19 | 9.85 |
| 20 | 14.84 |
| 21 | 13.71 |
| 24 | 12.43 |
| **Total MAPE** | **9.2535** |

Table 7: MAPE during School Holiday

| Week | MAPE Value (%) |
|---|---|
| 7 | 7.74 |
| 11 | 6.46 |
| 22 | 6.53 |
| 23 | 8.66 |
| **Total MAPE** | **7.3475** |

Table 8: Overall MAPE Percentage

| Week | MAPE Value (%) |
|---|---|
| 1 | 7.50 |
| 2 | 11.49 |
| 3 | 12.41 |
| 4 | 8.43 |
| 5 | 5.61 |
| 6 | 3.46 |
| 7 | 7.74 |
| 8 | 6.33 |
| 9 | 5.88 |
| 10 | 5.73 |
| 11 | 6.46 |
| 12 | 11.82 |
| 13 | 8.36 |
| 14 | 9.47 |
| 15 | 7.32 |
| 16 | 11.56 |
| 17 | 7.88 |
| 18 | 10.89 |
| 19 | 9.85 |
| 20 | 14.84 |
| 21 | 13.71 |
| 22 | 6.53 |
| 23 | 8.66 |
| 24 | 12.43 |
| **Total MAPE** | **8.93** |

The total parking space demand fluctuates depending on the day of the week. Studies on the parking space demand behaviour and its special pattern are required as to understand why certain number is rising and others decreasing. It is noticed that the parking space demand on a particular weekday is not largely differs from the day before. However, the demands during weekend rose drastically.

The graphs showed the forecasted parking versus actual parking data during school day and school holiday in the Figure 17 and 18 below:

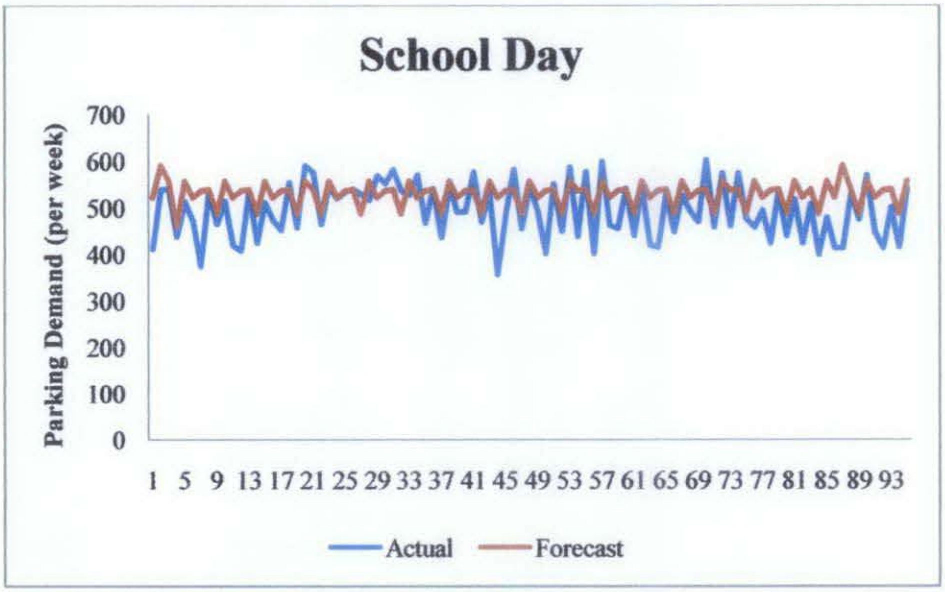



Figure 17: Graph of Actual Vs Forecasted Parking Data (School Day)

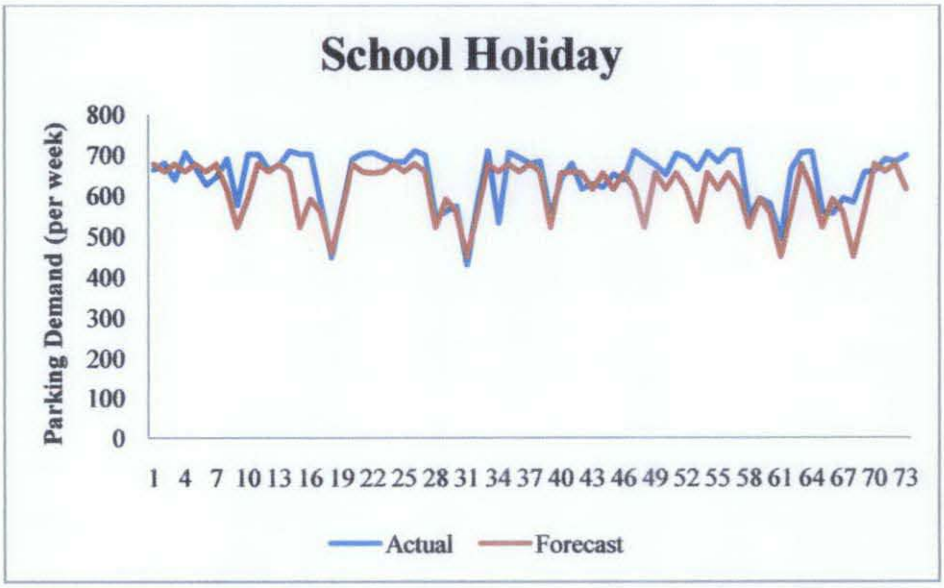



Figure 18: Graph of Actual Vs Forecasted Parking Data (School Holiday)

The graphs showed the fluctuations of actual parking data during weekdays and weekends in the Figure 19, 20 and 21 below:

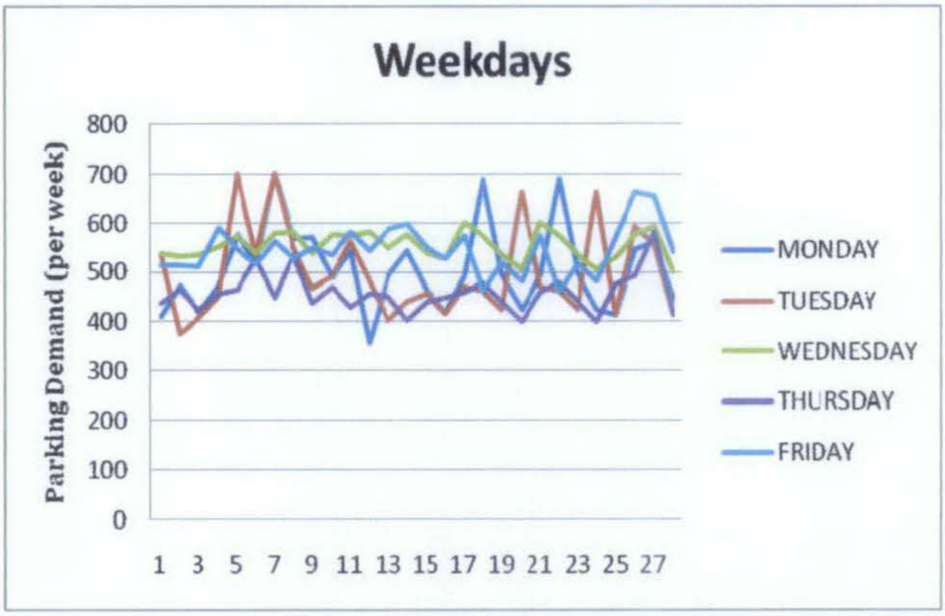



Figure 19: Graph of Actual Parking Data (Weekdays)

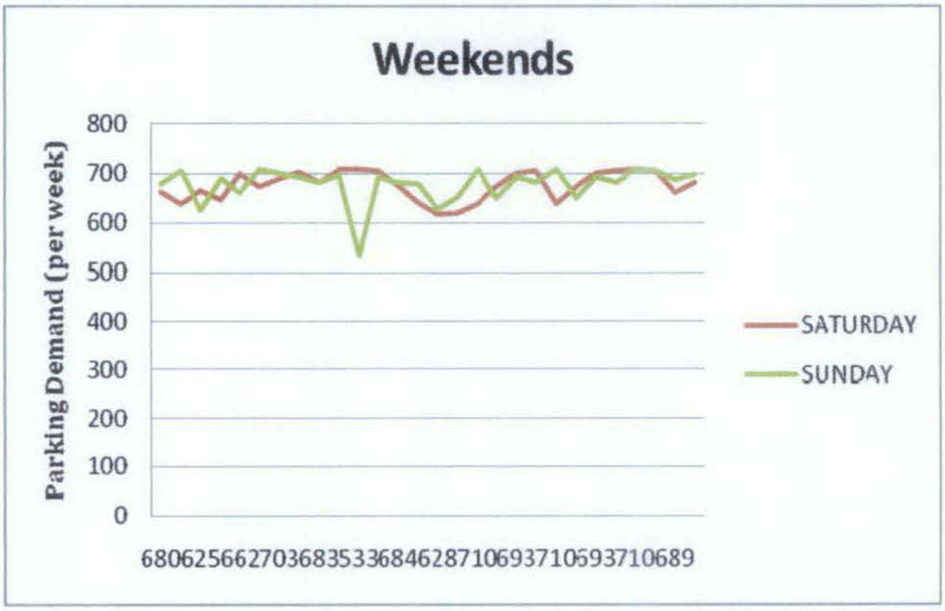



Figure 20: Graph of Actual Parking Data (Weekends)

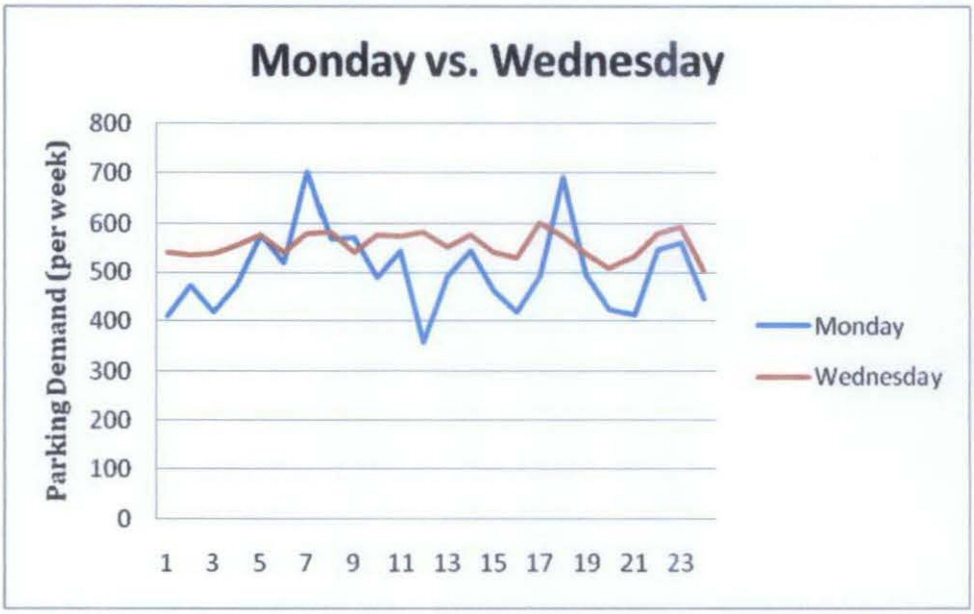



Figure 21: Graph of Actual Parking Data (Monday Vs Wednesday)

### 4.3 DISCUSSION

Simulations have been carried on for every day of the week on the same forecast models to determine the forecasted parking spaces. The overall MAPE is calculated by taking into calculation each week's MAPE. The overall MAPE result is 8.93, where MAPE during school day is 9.2535 and MAPE during school holidays is 7.3475. The forecasting methodology with fuzzy parameters gives acceptable short-range parking demand forecasting results and they are below the range of 10% MAPE.

From observation, by changing the degree of support for the rules, there are two possible effects. First, either all the week related to the rules are experiencing MAPE decrement or some rules are facing MAPE decrement and some are increased. Thus, it is very crucial to balance the DoS adjustment so as to balance and keep minimum all the MAPE.

From this project, we can conclude that the influence of geographical location of Wangsa Walk Mall is the determining factor in parking space demand forecasting. As stated before, there are almost 43 schools in three kilometre perimeter such as Seri Utama Private School, Kolej Tunku Abdul Rahman, SK/SMK Padang Tembak, SK/SMK Desa Tun Hussein Onn, SK Polis Depot, SK/SMK Taman Setiawangsa, Consist College, SK/SMK Setapak Indah, SK/SMK Wangsa Melawati, SK/SMK Danau Kota, SK/SMK Lembah Keramat, Institute Media Icon, CECE Institute, SK/SMK Wangsa Jaya, Malaysian Institute of Art (MIA), SK/SMK Air Panas, SK Marian Convent, SK/SMK Taman Seri Rampai, SMK Wangsa Maju Seksyen 5 and SMK Zon R1 Wangsa Maju.

The map in Figure 22 shows the location of the Wangsa Walk Mall with the surrounding schools in three kilometre perimeter below:

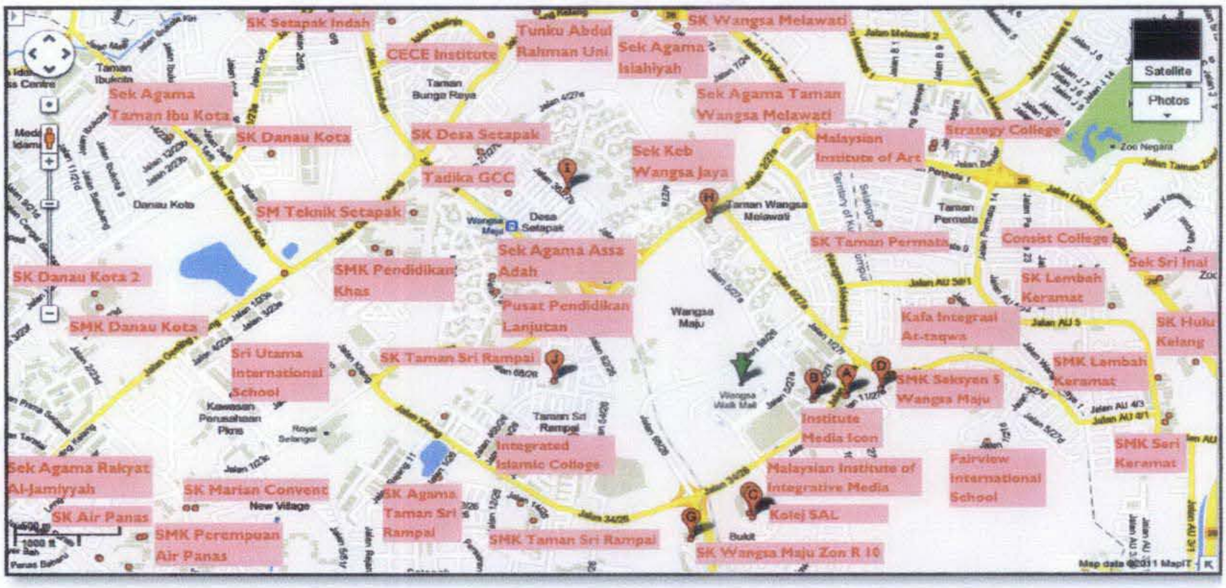



Figure 22: Wangsa Walk Mall Location

Another contributing factor would be the day type which is public holiday, normal working day and special event that are conducted by the shopping mall. We can see that during public holiday, the normal parking occupancy rose drastically, as drastic as during special occasion.

Special events that are conducted at Wangsa Walk Mall for the past six months between 3 January 2011 and 19 June 2011 are Superstar Karaoke Season 2 @WangsaWalk, Crime Prevention Awareness Day, Fun Chess Move @WM, 1Malaysia Mega Sales and Chinese New Year Sales. These events attracted thousands of visitors around the Federal Territory of Kuala Lumpur where parking demand will rises drastically which up to the point the parking spaces could not occupy all the expected visitors.

In addition, on Monday the parking demand is low compared to other day of the week as less people came due to it is the first day of the week. During public holiday, demand rose drastically on any day of the week. As example on Monday, there are Thaipusam, KL Day and Labour Day on week 5, 6 and 18 respectively. On Wednesday which is TGV Cinemas Movie Day, parking demand is steadily high throughout 24 weeks as every Wednesday the movie is sold out.

Results of the forecasting show that the number of parking spaces is inadequate. Maximum occupancy for Wangsa Walk Mall's parking spaces during a period of time is 670. However, forecasting result shown over 700 spaces is needed. The excess number is contributed by the cars that are going around Wangsa Walk Mall in search of parking space even though it is already full. Wangsa Walk Mall should have future plans to add more parking to cater more visitors.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATION

## 5.1 CONCLUSION

Short-range parking demand forecasting was performed for the month of January until June in a data set of 24 weeks. The forecasting methodology with fuzzy parameters gives acceptable short-range parking demand forecasting results and they are below the range of 10% MAPE. The modification on DoS and IF-THEN rules on each rule blocks show significant decrement in the MAPE.

## 5.2 RECOMMENDATION

For the next semester, it is recommended to expand the membership function and to increase the number of rules. If the numbers of rules are increased, this may improve the system model accuracy. It is recommended to add the rule of population growth rate of Wangsa Maju residential area as the input variable to the forecasting model.

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# APPENDIX

**APPENDIX A**

WANGSA WALK PARKING DEMAND FOR YEAR 2011 (3Jan2011-19June2011)

| Week No. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| MONDAY | 412 | 473 | 420 | 475 |
| TUESDAY | 539 | 375 | 408 | 452 |
| WEDNESDAY | 541 | 534 | 537 | 554 |
| THURSDAY | 438 | 466 | 425 | 458 |
| FRIDAY | 514 | 515 | 512 | 590 |
| SATURDAY | 663 | 638 | 667 | 646 |
| SUNDAY | 680 | 706 | 625 | 690 |
| Average Weekday Parking | 488.8 | 472.6 | 460.4 | 505.8 |
| Comment(s) | | | | Thaipusam |

| Week No. | 5 | 6 | 7 | 8 |
|---|---|---|---|---|
| MONDAY | 576 | 520 | 702 | 569 |
| TUESDAY | 701 | 535 | 701 | 552 |
| WEDNESDAY | 576 | 540 | 580 | 582 |
| THURSDAY | 465 | 529 | 449 | 536 |
| FRIDAY | 546 | 517 | 563 | 528 |
| SATURDAY | 701 | 674 | 690 | 705 |
| SUNDAY | 662 | 709 | 703 | 693 |
| Average Weekday Parking | 573.4 | 528.2 | 600.6 | 553.4 |
| Comment(s) | Thaipusam | | Chinese New Year | Maulidur |
| | KL Day | | Chap Goh Mei | Rasul |

| Week No. | 9 | 10 | 11 | 12 |
|---|---|---|---|---|
| MONDAY | 571 | 491 | 544 | 357 |
| TUESDAY | 468 | 492 | 562 | 484 |
| WEDNESDAY | 541 | 577 | 574 | 582 |
| THURSDAY | 437 | 470 | 431 | 456 |
| FRIDAY | 548 | 536 | 582 | 545 |
| SATURDAY | 682 | 710 | 709 | 706 |
| SUNDAY | 683 | 699 | 533 | 693 |
| Average Weekday Parking | 513 | 513.2 | 538.6 | 484.8 |
| Comment(s) | | | School Holiday | |

| Week No. | 13 | 14 | 15 | 16 |
|---|---|---|---|---|
| MONDAY | 493 | 544 | 463 | 420 |
| TUESDAY | 402 | 439 | 456 | 416 |
| WEDNESDAY | 551 | 577 | 541 | 530 |
| THURSDAY | 451 | 402 | 441 | 449 |
| FRIDAY | 587 | 599 | 549 | 527 |
| SATURDAY | 678 | 641 | 616 | 620 |
| SUNDAY | 684 | 679 | 628 | 652 |
| Average Weekday Parking | 496.8 | 512.2 | 490 | 468.4 |
| Comment(s) | | Hindu New Year | Fun Moves Chess @WM | Fun Moves Chess @WM |
| | | Crime Prevention Awareness Day | | Easter Day |

| Week No. | 17 | 18 | 19 | 20 |
|---|---|---|---|---|
| MONDAY | 493 | 692 | 495 | 424 |
| TUESDAY | 471 | 462 | 424 | 664 |
| WEDNESDAY | 602 | 574 | 537 | 508 |
| THURSDAY | 460 | 478 | 440 | 400 |
| FRIDAY | 574 | 459 | 519 | 480 |
| SATURDAY | 638 | 675 | 703 | 708 |
| SUNDAY | 710 | 651 | 693 | 682 |
| Average Weekday Parking | 520 | 533 | 483 | 495.2 |
| Comment(s) | Superstar Karaoke | Labour Day | Superstar Karaoke | Wesak Day |
| | Labour Day | Superstar Karaoke | | Superstar Karaoke |

| Week No. | 21 | 22 | 23 | 24 |
|---|---|---|---|---|
| MONDAY | 414 | 548 | 560 | 448 |
| TUESDAY | 414 | 592 | 556 | 414 |
| WEDNESDAY | 532 | 579 | 593 | 502 |
| THURSDAY | 476 | 494 | 583 | 416 |
| FRIDAY | 570 | 664 | 657 | 540 |
| SATURDAY | 710 | 706 | 660 | 683 |
| SUNDAY | 710 | 708 | 689 | 699 |
| Average Weekday Parking | 481.2 | 575.4 | 589.8 | 464 |
| Comment(s) | Superstar Karaoke (Finale) | School Holiday | School Holiday | Father's Day |

**APPENDIX B**

PARKING DEMAND SUMMARY

| MONDAY | TUESDAY | WEDNESDAY | THURSDAY | FRIDAY | SATURDAY | SUNDAY |
|---|---|---|---|---|---|---|
| 412 | 539 | 541 | 438 | 514 | 663 | 680 |
| 473 | 375 | 534 | 466 | 515 | 638 | 706 |
| 420 | 408 | 537 | 425 | 512 | 667 | 625 |
| 475 | 452 | 554 | 458 | 590 | 646 | 690 |
| 576 | 701 | 576 | 465 | 546 | 701 | 662 |
| 520 | 535 | 540 | 529 | 517 | 674 | 709 |
| 702 | 701 | 580 | 449 | 563 | 690 | 703 |
| 569 | 552 | 582 | 536 | 528 | 705 | 693 |
| 571 | 468 | 541 | 437 | 548 | 682 | 683 |
| 491 | 492 | 577 | 470 | 536 | 710 | 699 |
| 544 | 562 | 574 | 431 | 582 | 709 | 533 |
| 357 | 484 | 582 | 456 | 545 | 706 | 693 |
| 493 | 402 | 551 | 451 | 587 | 678 | 684 |
| 544 | 439 | 577 | 402 | 599 | 641 | 679 |
| 463 | 456 | 541 | 441 | 549 | 616 | 628 |
| 420 | 416 | 530 | 449 | 527 | 620 | 652 |
| 493 | 471 | 602 | 460 | 574 | 638 | 710 |
| 692 | 462 | 574 | 478 | 459 | 675 | 651 |
| 495 | 424 | 537 | 440 | 519 | 703 | 693 |
| 424 | 664 | 508 | 400 | 480 | 708 | 682 |
| | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 414 | 414 | 532 | 476 | 570 | 710 | 710 |
| 548 | 592 | 579 | 494 | 664 | 706 | 708 |
| 560 | 556 | 593 | 583 | 657 | 660 | 689 |
| 448 | 414 | 502 | 416 | 540 | 683 | 699 |
| 504.3 | 499.6 | 556 | 460.4 | 550.9 | 676.2 | 677.5 |
| | | | | | | |
| MAX 702 | 701 | 602 | 583 | 664 | 710 | 710 |
| MIN 357 | 375 | 502 | 400 | 459 | 616 | 533 |
| SUM 12104 | 11990 | 13344 | 11050 | 13221 | 16229 | 16261 |

# APPENDIX C
MEMBERSHIP FUNCTIONS

**Input Variables**

Day Type

| | |
|---|---|
| Public Holiday | 1 |
| Normal Day | 2 |
| Special Occasion | 3 |

Special Occasion: Sale, Public Event, Celebrity Appearance, Company Event

School Type

| | |
|---|---|
| School Holiday | 1 |
| School Day | 2 |

**Output Variables**

Forecasted Parking Demand: Monday

| | |
|---|---|
| Very Low | 300-437 units |
| Low | 437-471 units |
| Medium | 471-573 units |
| High | 573-642 units |
| Very High | 642-702 units |

Forecasted Parking Demand: Tuesday

| | |
|---|---|
| Very Low | 300-437 units |
| Low | 437-471 units |
| Medium | 471-573 units |
| High | 573-642 units |
| Very High | 642-702 units |

Forecasted Parking Demand: Wednesday

| | |
|---|---|
| Very Low | 440-510 units |
| Low | 510-545 units |
| Medium | 545-580 units |
| High | 580-615 units |
| Very High | 615-650 units |

Forecasted Parking Demand: Thursday

| | |
|---|---|
| Very Low | 350-410 units |
| Low | 410-450 units |
| Medium | 450-530 units |
| High | 530-575 units |
| Very High | 575-620 units |

Forecasted Parking Demand: Friday

| | |
|---|---|
| Very Low | 400-500 units |
| Low | 500-535 units |
| Medium | 535-600 units |
| High | 600-650 units |
| Very High | 650-700 units |

Forecasted Parking Demand: Saturday

| | |
|---|---|
| Very Low | 600-625 units |
| Low | 625-640 units |
| Medium | 640-670 units |
| High | 670-693 units |
| Very High | 693-710 units |

Forecasted Parking Demand: Sunday

| | |
|---|---|
| Very Low | 500-570 units |
| Low | 570-600 units |
| Medium | 600-640 units |
| High | 640-675 units |
| Very High | 675-710 units |

**APPENDIX D**
WANGSA WALK MALL FIGURES


Figure A: Wangsa Walk Mall Parking Space (North)

Figure B: Wangsa Walk Mall Parking Space (South)


Figure C: Wangsa Walk Mall Parking Payment Counter (Front)


Figure D: Wangsa Walk Mall Parking Management Department (Back)