
John Tin Yuan En

Doctor of Philosophy
2018
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This declaration is made on the 8th day of October, 2018.

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Date submitted: 8/10/2018

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John Tin Yuan En

A thesis submitted
In fulfillment of the requirements for the degree of Doctor of Philosophy
(Electrical and Electronics Engineering)

Faculty of Engineering
UNIVERSITI MALAYSIA SARAWAK
2018
DECLARATION

I, John Tin Yuan En (11011558) from Faculty of Engineering UNIMAS hereby declare
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Buildings in Sarawak Urban Areas is my original work. I have not copied from any other
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John Tin Yuan En (11011558)
Date:
ACKNOWLEDGEMENT

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ABSTRACT

Energy consumption of building sectors has increased rapidly due to the improved living standard and the rise of resident’s expectations on thermal comfort. Mechanical ventilations especially air conditioning system is essential for hot and humid countries to achieve their ideal indoor comfort condition. However, such cooling system consumes a huge amount of electricity which is in contradiction with the concept of energy conservation. Thermal comfort assessment is one of the methods to overcome this issue. It evaluates the thermal perception of the occupants and consecutively facilitates the efficient usage of mechanical ventilation systems and attains the purpose of saving the energy. Steady state model and adaptive model are the two main approaches to evaluate thermal comfort. Fanger’s Predicted Mean Vote (PMV) model is a prevalent example of steady state model where environmental and personal factors are comprised. On the other hand, adaptive model involves comfort temperature and outdoor temperature to predict the thermal comfort of the indoor environment. Several research studies have indicated that PMV model is not applicable on tropical buildings as it often overestimates the actual thermal sensation of the occupants. Conversely, adaptive model is found to be expressing occupants’ thermal perception competently. In this study, thermal comfort analysis was carried out on the free running residential buildings in Sarawak which were naturally ventilated with minimal usage of mechanical ventilation systems. Physical measurements and subjective assessments were performed to evaluate the thermal responses of 287 residents based on ASHRAE scale, Bedford scale, thermal acceptability scale and thermal preference scale. PMV model was also used to predict the thermal sensation of the residents. Bedford scale showed the highest percentage of acceptable votes followed by
ASHRAE scale, thermal acceptability scale and thermal preference scale. The comfort temperatures of the study were obtained from ASHRAE scale, Bedford scale and PMV model which were found to be 27.5 °C, 28.1 °C and 26.2 °C respectively. The adaptive thermal comfort models were proposed based on the responses of residents on ASHRAE scale and Bedford scale. According to actual percentage dissatisfied which fulfilled 80% satisfaction, the upper and lower limit of the model for indoor operative temperature, relative humidity and air velocity were from 27.3 °C to 29.6 °C, 74.0% to 92.0 % and 0.18 ms$^{-1}$ to 0.66 ms$^{-1}$ respectively.

**Keywords:** Thermal comfort; residential buildings; adaptive model; comfort temperature; ASHRAE scale; Bedford scale
Perekaan Model Keselesaan Terma Adaptif untuk Bangunan Kediaman di Kawasan Bandar Sarawak

ABSTRAK

Penggunaan tenaga dalam sektor bangunan telah meningkat dengan drastik disebabkan oleh taraf kehidupan dan permintaan penduduk yang semakin meningkat terhadap keselesaan terma. Pengudaraan mekanikal terutamanya sistem penyaman udara memainkan peranan yang penting untuk negara-negara yang mengalami iklim panas dan lembap demi mencapai keselesaan terma yang memuaskan. Walau bagaimanapun, sistem penyejukan tersebut memerlukan penggunaan elektrik yang besar dan fenomena ini adalah bertentangan dengan konsep pemuliharaan tenaga. Penilaian keselesaan terma merupakan salah satu cara penyesuaian untuk mengatasi masalah tersebut. Cara ini menilai persepsi terma penduduk-penduduk kediaman untuk memastikan penggunaan pengalihudaraan mekanikal secara berkesan dan stereusnya mencapai tujuan penjimatan tenaga. Model keadaan mantap dan model penyesuaian adalah dua pendekatan utama untuk menilai keselesaan terma. Model Fanger Predicted Mean Vote (PMV) ialah salah satu contoh model keadaan mantap yang melibatkan faktor persekitaran dan faktor manusia. Sebaliknya, model penyesuaian melibatkan suhu selesa dan suhu persekitaran luar untuk meramalkan keselesaan terma dalam persekitaran yang tertutup. Beberapa kajian penyelidikan telah menunjukkan bahawa model PMV tidak sesuai untuk digunakan di atas bangunan - bangunan yang beriklim tropika kerana ia sering meremehkan sensasi haba yang dialami oleh para penghuni. Model adaptif pula dikesan dapat menyampaikan persepsi terma penghuni dengan lebih tepat. Dalam penyelidikan ini, kawasan-kawasan perumahan Sarawak yang menggunakan sistem pengudaraan semula jadi dan sistem
pengudaraan mekanikal telah disiasat dari segi keselesaan terma. Tindak balas terma
daripada 287 penduduk tempatan telah dianalisis melalui pengukuran fizikal persekitaran
dan penilaian subjek berdasarkan soal-soal penyelidikan dengan menggunakan skala
ASHRAE, skala Bedford, skala penerimaan terma dan skala kegemaran terma. Model
PMV juga digunakan untuk meramalkan reaksi penduduk-­penduduk terhadap keadaan
persekitran mereka. Skala Bedford memaparkan peratusan penerimaan yang tertinggi
diikuti oleh skala ASHRAE, skala penerimaan terma dan skala kegemaran terma. Suhu
selesa yang diperolehi daripada skala ASHRAE, skala Bedford dan model PMV masing-
masing adalah 27.5 ℃, 28.1 ℃ dan 26.2 ℃. Model-model keselesaan terma adaptif ini
adalah dibina berdasarkan maklumat-maklumat yang dibekalkan oleh para penduduk
melalui skala ASHRAE dan skala Bedford. Untuk memastikan model-model yang dibina ini
memenuhi kepuasan para penduduk sebanyak 80%, had batasan untuk model ini dari segi
suhu, tahap kelembapan dan halaju udara adalah dari 27.3 ℃ hingga 29.6 ℃, 74.0%
hingga 92.0% dan 0.18 ms⁻¹ hingga 0.66 ms⁻¹.

Kata kunci: Keselesaan terma; kawasan perumahan; model adaptif; suhu selesa; skala
ASHRAE; skala Bedford
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>DECLARATION</td>
<td>i</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENT</td>
<td>ii</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>iii</td>
</tr>
<tr>
<td>ABSTRAK</td>
<td>v</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>xiii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xviii</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td>xxiii</td>
</tr>
<tr>
<td>CHAPTER 1: INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Research Background</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Problem Statements</td>
<td>2</td>
</tr>
<tr>
<td>1.3 Objectives of the Study</td>
<td>4</td>
</tr>
<tr>
<td>1.4 Expected Outcomes</td>
<td>4</td>
</tr>
<tr>
<td>1.5 Structure of the Thesis</td>
<td>5</td>
</tr>
<tr>
<td>CHAPTER 2: LITERATURE REVIEW</td>
<td>6</td>
</tr>
<tr>
<td>2.1 Overview</td>
<td>6</td>
</tr>
<tr>
<td>2.2 Energy Trend in Malaysia</td>
<td>6</td>
</tr>
<tr>
<td>2.2.1 Fuel Mix Electricity Generation</td>
<td>6</td>
</tr>
<tr>
<td>2.2.2 Energy in Demand by Sector</td>
<td>10</td>
</tr>
<tr>
<td>2.2.3 Energy Supply in Malaysia by Source</td>
<td>12</td>
</tr>
</tbody>
</table>
## 2.3 Cooling System

2.3.1 Passive Cooling System

2.3.2 Developments of Passive Cooling System in Different Climates

2.3.3 Active Cooling System

2.3.4 Developments of Hybrid Cooling System in Different Climates

## 2.4 Thermal Comfort

2.4.1 Approaches of Thermal Comfort

2.4.2 Factors of PMV and PPD

2.4.3 Weakness of PMV Model

2.4.4 Adaptive Principle

## 2.5 Adaptive Thermal Comfort Models

## 2.6 The Impact of Different Thermal Comfort Models on Zero Energy Residential Buildings

## 2.7 Chapter Summary

### CHAPTER 3: METHODOLOGY

3.1 Overview

3.2 Field Measurements

3.2.1 Physical Measurements

3.2.1.1 Hygrometer Model Testo 625

3.2.1.2 Hot Wire Anemometer Model TA 888

3.2.1.3 Globe Thermometer

3.2.2 Subjective Assessments
3.3 Validation Test for Measurements Data 65
3.4 Thermal Comfort Evaluation 65
  3.4.1 ASHRAE Scale 66
    3.4.1.1 Analysis of Comfort Temperature, \( T_c \) from ASHRAE Scale 66
  3.4.2 Bedford Scale 67
    3.4.2.1 Analysis of Comfort Temperature, \( T_c \) from Bedford Scale 68
  3.4.3 Fanger’s Model 68
    3.4.3.1 Analysis of Comfort Temperature, \( T_c \) from Fanger’s Model 69
  3.4.4 Thermal Acceptability Scale 69
  3.4.5 Thermal Preference Scale 70
  3.4.6 Analysis of Relative Humidity 70
  3.4.7 Analysis of Air Velocity 71
3.5 Proposed Adaptive Thermal Comfort Model 71
  3.5.1 Upper and Lower Limit of the Adaptive Model 72
  3.5.2 Validation of the Adaptive Model 73
3.6 Chapter Summary 73

CHAPTER 4: RESULTS AND DISCUSSION 76
4.1 Overview 76
4.2 Field Measurements Results 77
  4.2.1 Indoor and Outdoor Environmental Parameters 77
    4.2.1.1 Air Temperature 77
<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.2.1.2</td>
<td>Globe Temperature</td>
<td>78</td>
</tr>
<tr>
<td>4.2.1.3</td>
<td>Mean Radiant Temperature</td>
<td>79</td>
</tr>
<tr>
<td>4.2.1.4</td>
<td>Operative Temperature</td>
<td>79</td>
</tr>
<tr>
<td>4.2.1.5</td>
<td>Outdoor Temperature</td>
<td>80</td>
</tr>
<tr>
<td>4.2.1.6</td>
<td>Relative Humidity</td>
<td>81</td>
</tr>
<tr>
<td>4.2.1.7</td>
<td>Air Velocity</td>
<td>82</td>
</tr>
<tr>
<td>4.2.1.8</td>
<td>Bias Uncertainty</td>
<td>83</td>
</tr>
<tr>
<td>4.2.2</td>
<td>Personal Parameters</td>
<td>87</td>
</tr>
<tr>
<td>4.2.2.1</td>
<td>Clothing Insulation</td>
<td>88</td>
</tr>
<tr>
<td>4.2.2.2</td>
<td>Activity Level</td>
<td>88</td>
</tr>
<tr>
<td>4.2.3</td>
<td>Average Indoor Operative Temperature vs Average Outdoor Temperature</td>
<td>89</td>
</tr>
<tr>
<td>4.2.4</td>
<td>Average Relative Humidity vs Average Indoor Operative Temperature</td>
<td>90</td>
</tr>
<tr>
<td>4.2.5</td>
<td>Average Air Velocity vs Average Indoor Operative Temperature</td>
<td>92</td>
</tr>
<tr>
<td>4.2.6</td>
<td>Clothing Insulation vs Indoor Operative Temperature</td>
<td>94</td>
</tr>
<tr>
<td>4.2.7</td>
<td>Activity Level vs Indoor Operative Temperature</td>
<td>95</td>
</tr>
<tr>
<td>4.3</td>
<td>Thermal Comfort Analysis</td>
<td>97</td>
</tr>
<tr>
<td>4.3.1</td>
<td>Thermal Perception of Respondents on ASHRAE Scale</td>
<td>97</td>
</tr>
<tr>
<td>4.3.2</td>
<td>Thermal Perception of Respondents on Bedford Scale</td>
<td>99</td>
</tr>
<tr>
<td>4.3.3</td>
<td>ASHRAE Scale vs Bedford Scale</td>
<td>100</td>
</tr>
<tr>
<td>4.3.4</td>
<td>Thermal Acceptability Scale</td>
<td>102</td>
</tr>
<tr>
<td>4.3.5</td>
<td>Thermal Acceptability Scale vs ASHRAE Scale</td>
<td>104</td>
</tr>
</tbody>
</table>
4.8.1.8 Residential Area 8 146
4.8.1.9 Residential Area 9 147
4.8.1.10 Residential Area 10 149
4.8.2 Correlation of Average Relative Humidity with Comfort Temperature of TSV and TCV 150
4.8.3 Correlation of Average Air Velocity with Comfort Temperature of TSV and TCV 153
4.8.4 Regression Analysis between Thermal Neutrality and Average Outdoor Temperature of each Residential Area 156
4.8.5 Upper and Lower Limit of the Adaptive Models 160
  4.8.5.1 Operative Temperature 160
  4.8.5.2 Relative Humidity 165
  4.8.5.3 Air Velocity 168
4.9 Validation of the Adaptive Thermal Comfort Models 172
  4.9.1 Thermal Comfort Analysis 173
  4.9.2 Discrepancy between Comfort Temperature Values 179
4.10 Chapter Summary 183

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS 184
5.1 Conclusion 184
5.2 Recommendations 188

REFERENCES 190
APPENDICES 208
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Fuel Mix Electricity Generation</td>
<td>7</td>
</tr>
<tr>
<td>2.2</td>
<td>Final Commercial Energy Demand by Sector</td>
<td>10</td>
</tr>
<tr>
<td>2.3</td>
<td>Primary Commercial Energy Supply by Source</td>
<td>12</td>
</tr>
<tr>
<td>2.4</td>
<td>Classification of Passive Cooling System</td>
<td>14</td>
</tr>
<tr>
<td>2.5</td>
<td>Developments of Passive Cooling system</td>
<td>16</td>
</tr>
<tr>
<td>2.6</td>
<td>Developments of Hybrid Cooling System</td>
<td>21</td>
</tr>
<tr>
<td>2.7</td>
<td>Recommendations of ASHRAE Standard</td>
<td>26</td>
</tr>
<tr>
<td>2.8</td>
<td>Thermal Comfort Temperature of Different Climates</td>
<td>26</td>
</tr>
<tr>
<td>2.9</td>
<td>Adaptive Thermal Comfort Models</td>
<td>48</td>
</tr>
<tr>
<td>2.10</td>
<td>Annual Energy Consumption of Four Thermal Comfort Models</td>
<td>53</td>
</tr>
<tr>
<td>3.1</td>
<td>Factor Accordance of Air Velocity</td>
<td>63</td>
</tr>
<tr>
<td>3.2</td>
<td>Activity Level</td>
<td>64</td>
</tr>
<tr>
<td>3.3</td>
<td>Clothing Insulation</td>
<td>64</td>
</tr>
<tr>
<td>3.4</td>
<td>ASHRAE Scale</td>
<td>66</td>
</tr>
<tr>
<td>3.5</td>
<td>Bedford Scale</td>
<td>67</td>
</tr>
<tr>
<td>3.6</td>
<td>Thermal Acceptability Scale</td>
<td>70</td>
</tr>
<tr>
<td>3.7</td>
<td>Thermal Preference Scale</td>
<td>70</td>
</tr>
<tr>
<td>3.8</td>
<td>Scale for Relative Humidity</td>
<td>71</td>
</tr>
<tr>
<td>3.9</td>
<td>Scale for Air Velocity</td>
<td>71</td>
</tr>
<tr>
<td>4.1</td>
<td>Average Air Temperature for each Residential Area</td>
<td>78</td>
</tr>
<tr>
<td>4.2</td>
<td>Average Globe Temperature for each Residential Area</td>
<td>78</td>
</tr>
<tr>
<td>4.3</td>
<td>Average Mean Radiant Temperature for each Residential Area</td>
<td>79</td>
</tr>
</tbody>
</table>
Table 4.4  Average Operative Temperature for each Residential Area  80
Table 4.5  Average Outdoor Temperature for each Residential Area  81
Table 4.6  Average Relative Humidity for each Residential Area  81
Table 4.7  Average Air Velocity for each Residential Area  82
Table 4.8  Bias Uncertainty for Air Temperature  83
Table 4.9  Bias Uncertainty for Globe Temperature  84
Table 4.10  Bias Uncertainty for Relative Humidity  85
Table 4.11  Bias Uncertainty for Air Velocity  86
Table 4.12  Bias Uncertainty for Outdoor Temperature  87
Table 4.13  Average Clothing Insulation for each Residential Area  88
Table 4.14  Average Activity Level for each Residential Area  89
Table 4.15  Average Indoor Operative Temperature vs Average Outdoor Temperature  90
Table 4.16  Average Relative Humidity vs Average Indoor Operative Temperature  91
Table 4.17  Average Air Velocity vs Average Indoor Operative Temperature  93
Table 4.18  Average Clothing Insulation vs Average Indoor Operative Temperature  95
Table 4.19  Average Activity Level vs Average Indoor Operative Temperature  97
Table 4.20  Distribution of Votes on ASHRAE Scale  99
Table 4.21  Distribution of Votes on Bedford Scale  100
Table 4.22  Cross-tabulation of Thermal Sensation Votes and Thermal Comfort Votes  102
Table 4.23  Votes on Thermal Acceptability Scale  103
Table 4.24  Percentage of Acceptable Votes on ASHRAE Scale
Table 4.25  Percentage of Acceptable Votes on Bedford Scale
Table 4.26  Thermal Preference Scale
Table 4.27  Thermal Preference Scale vs Thermal Acceptability Scale
Table 4.28  Thermal Preference Scale vs ASHRAE Scale
Table 4.29  Thermal Preference Scale vs Bedford Scale
Table 4.30  Percentage of Acceptable Votes for Various Scales
Table 4.31  Mean Thermal Sensation Votes
Table 4.32  Mean Thermal Comfort Votes
Table 4.33  Predicted Mean Votes
Table 4.34  Value Comparison between TSV, TCV and PMV
Table 4.35  Average Relative Humidity and Relative Humidity Vote (RHV)
Table 4.36  Average Air Speed and Mean Air Speed Vote (ASV)
Table 4.37  TSV, TCV, Indoor Operative and Outdoor Temperature for Residential Area 1
Table 4.38  TSV, TCV, Indoor Operative and Outdoor Temperature for Residential Area 2
Table 4.39  TSV, TCV, Indoor Operative and Outdoor Temperature for Residential Area 3
Table 4.40  TSV, TCV, Indoor Operative and Outdoor Temperature for Residential Area 4
Table 4.41  TSV, TCV, Indoor Operative and Outdoor Temperature for Residential Area 5
Table 4.42  TSV, TCV, Indoor Operative and Outdoor Temperature for
Table 4.43  TSV, TCV, Indoor Operative and Outdoor Temperature for Residential Area 7
Table 4.44  TSV, TCV, Indoor Operative and Outdoor Temperature for Residential Area 8
Table 4.45  TSV, TCV, Indoor Operative and Outdoor Temperature for Residential Area 9
Table 4.46  TSV, TCV, Indoor Operative and Outdoor Temperature for Residential Area 10
Table 4.47  Comfort Temperature of ASHRAE Scale, Bedford Scale and Average Relative Humidity for each Residential Area
Table 4.48  Comfort Temperature of ASHRAE Scale, Bedford Scale and Average Air Speed for each Residential Area
Table 4.49  Comfort Temperature from ASHRAE Scale and Bedford Scale and Average Outdoor Temperature
Table 4.50  Actual Percentage Dissatisfied, Predicted Percentage Dissatisfied for each Operative Temperature
Table 4.51  Actual Percentage Dissatisfied, Predicted Percentage Dissatisfied for each Relative Humidity
Table 4.52  Actual Percentage Dissatisfied, Predicted Percentage Dissatisfied for each Air Velocity
Table 4.53  Distribution of Votes on ASHRAE Scale
Table 4.54  Distribution of Votes on Bedford Scale
Table 4.55  Cross-tabulation of Thermal Sensation Votes and Thermal Comfort

xvi
<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.56</td>
<td>Percentage of Acceptable Votes for Various Scale</td>
<td>175</td>
</tr>
<tr>
<td>4.57</td>
<td>Measurements for the Validation Study</td>
<td>176</td>
</tr>
<tr>
<td>4.58</td>
<td>Comfort Temperature from Experiment, Validation Test and Experimental Models</td>
<td>179</td>
</tr>
</tbody>
</table>

Table 4.58: Comfort Temperature from Experiment, Validation Test and Experimental Models
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Acceptable Range of Operative Temperatures and Humidities for People in Typical Summer and Winter</td>
<td>25</td>
</tr>
<tr>
<td>3.1(a)</td>
<td>Set up of the Devices</td>
<td>59</td>
</tr>
<tr>
<td>3.1(b)</td>
<td>Devices Located 1.1m above the Floor Level</td>
<td>59</td>
</tr>
<tr>
<td>3.2</td>
<td>Hygrometer Model Testo 625</td>
<td>60</td>
</tr>
<tr>
<td>3.3</td>
<td>Hot Wire Anemometer Model TA 888</td>
<td>61</td>
</tr>
<tr>
<td>3.4</td>
<td>Globe Thermometer</td>
<td>61</td>
</tr>
<tr>
<td>3.5</td>
<td>Methodology Flow for Adaptive Thermal Comfort Model Development</td>
<td>75</td>
</tr>
<tr>
<td>4.1</td>
<td>Average Indoor Operative Temperature vs Average Outdoor Temperature</td>
<td>89</td>
</tr>
<tr>
<td>4.2</td>
<td>Average Relative Humidity vs Average Indoor Operative Temperature</td>
<td>91</td>
</tr>
<tr>
<td>4.3</td>
<td>Average Air Velocity vs Average Indoor Operative Temperature</td>
<td>92</td>
</tr>
<tr>
<td>4.4</td>
<td>Average Clothing Insulation vs Average Indoor Operative Temperature</td>
<td>94</td>
</tr>
<tr>
<td>4.5</td>
<td>Average Activity Level vs Average Indoor Operative Temperature</td>
<td>96</td>
</tr>
<tr>
<td>4.6</td>
<td>Distribution of Thermal Sensation Votes (TSV)</td>
<td>98</td>
</tr>
<tr>
<td>4.7</td>
<td>Distribution of Thermal Comfort Votes (TCV)</td>
<td>99</td>
</tr>
<tr>
<td>4.8</td>
<td>Distribution of Votes on ASHRAE Scale and Bedford scale</td>
<td>101</td>
</tr>
<tr>
<td>4.9</td>
<td>Distribution of Acceptability Votes</td>
<td>103</td>
</tr>
<tr>
<td>4.10</td>
<td>Thermal Acceptability Scale vs ASHRAE Scale</td>
<td>104</td>
</tr>
</tbody>
</table>
Figure 4.11  Thermal Acceptability Scale vs Bedford Scale  
Figure 4.12  Distribution of Thermal Preference Votes  
Figure 4.13  Thermal Preference Scale vs Thermal Acceptability  
Figure 4.14  Thermal Preference Scale vs ASHRAE Scale  
Figure 4.15  Thermal Preference Scale vs Bedford Scale  
Figure 4.16  Percentage of Acceptable Votes for Various Scales  
Figure 4.17  Thermal Sensation Votes against Indoor Operative Temperature  
Figure 4.18  Thermal Comfort Votes against Indoor Operative Temperature  
Figure 4.19  Predicted Mean Votes against Indoor Operative Temperature  
Figure 4.20  Regression Analysis between TSV and PMV  
Figure 4.21  Regression Analysis between TCV and TSV  
Figure 4.22  Regression Analysis between TCV and PMV  
Figure 4.23  Average Relative Humidity vs Mean Relative Humidity Vote  
Figure 4.24  Average Air Speed vs Mean Air Speed Vote  
Figure 4.25  Regression Analysis between TSV and Indoor Operative Temperature for Residential Area 1  
Figure 4.26  Regression Analysis between TCV and Indoor Operative Temperature for Residential Area 1  
Figure 4.27  Regression Analysis between TSV and Indoor Operative Temperature for Residential Area 2  
Figure 4.28  Regression Analysis between TCV and Indoor Operative Temperature for Residential Area 2  
Figure 4.29  Regression Analysis between TSV and Indoor Operative Temperature for Residential Area 3
Figure 4.30  Regression Analysis between TCV and Indoor Operative Temperature for Residential Area 3

Figure 4.31  Regression Analysis between TSV and Indoor Operative Temperature for Residential Area 4

Figure 4.32  Regression Analysis between TCV and Indoor Operative Temperature for Residential Area 4

Figure 4.33  Regression Analysis between TSV and Indoor Operative Temperature for Residential Area 5

Figure 4.34  Regression Analysis between TCV and Indoor Operative Temperature for Residential Area 5

Figure 4.35  Regression Analysis between TSV and Indoor Operative Temperature for Residential Area 6

Figure 4.36  Regression Analysis between TCV and Indoor Operative Temperature for Residential Area 6

Figure 4.37  Regression Analysis between TSV and Indoor Operative Temperature for Residential Area 7

Figure 4.38  Regression Analysis between TCV and Indoor Operative Temperature for Residential Area 7

Figure 4.39  Regression Analysis between TSV and Indoor Operative Temperature for Residential Area 8

Figure 4.40  Regression Analysis between TCV and Indoor Operative Temperature for Residential Area 8

Figure 4.41  Regression Analysis between TSV and Indoor Operative Temperature for Residential Area 9