A Field Assessment on Natural Ventilation and Thermal Comfort of Historical District

- A Case of the Wugoushui Settlement in Taiwan

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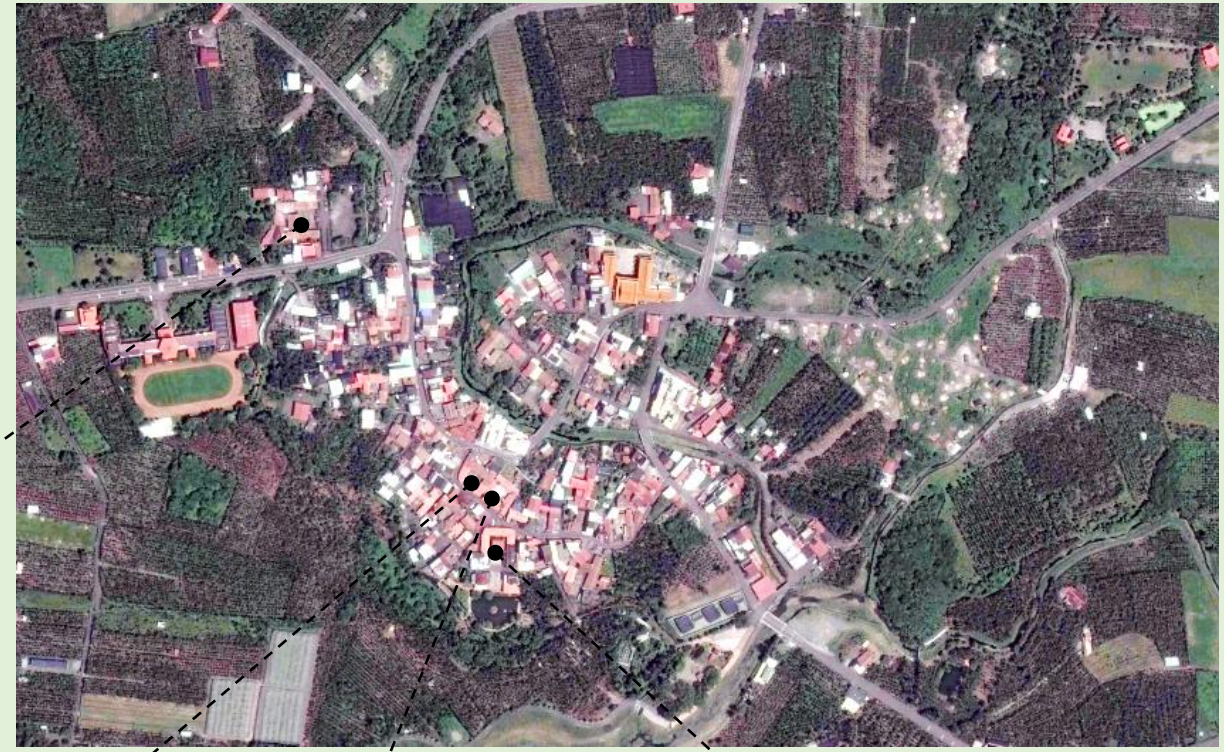
Study Area




Case A


Case C


Case D


Case B

- **The Problem of Historical Areas in Taiwan**

- **Study Purpose**

Understanding the indoor and outdoor thermal environmental situation in historic settlements and improve the indoor thermal comfort.

We used indoor and outdoor measurements under natural ventilation to find the factors affecting the thermal environment of historical buildings, assess the impact of outdoor wind speed on indoor wind speed, and **try to lower PMV values** through changes **wind speeds**, raising the thermal comfort levels of the historical buildings' indoor environment.

- **Results**

1. This study finds that **the building opening** is the main factor affecting the indoor comfort levels of historical buildings.
2. During the hottest time period of the hot season**, average indoor wind speed increases to 3.42 m/s**, effectively **reducing PMV values** to within the comfort zone.

PMV, TSV, PMV-PPD

- **Fanger's PMV Model (ISO 7730)**

- **Fanger's Modification (2002)**

  Countries with warm climates: the coefficient to between 0.5 and 1

  This study uses extended PMV, designating PMV<-1 and >+1 as unsatisfactory, -1<PMV<+1 as satisfactory, which is the range within which 80% of people feel satisfied to assess level of indoor thermal comfort.

- **TSV (ASHARE Standard 55)**

  Thermal sensation was measured by the conventional ASHRAE seven-point scale (thermal sensation vote, TSV), which comprises seven options.

Methods

- **Meteorological Data (2002 -2011)**
- **Field Experiment**

  Physical Environment Measurement

  1. Fixed Observation Station (11.3m, 02/2014 - 02/2015)
  2. Hot Season (2/02/2015 - 28/02/2015) , Cool Season (26/08/2014 - 30/09/2014)
     Outdoor Observation Station (1.5m)
     Indoor Observation Station (1.5m)

  Thermal Comfort Questionnaire

  There are about 500 longtime residents in Wugoushui Settlement. There are a total of 57 questionnaires, 33 for hot season and 24 for cool season.

- **Mean Radiant Temperature** (ISO 7726)

$$tmrt = [(t_g + 273)^4 + 0.4 \times 10^8 |t_g - t_a|^{\frac{1}{4}} \times (t_g - t_a)]^{1/4} - 273$$

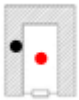
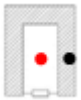
tg: Black bulb temperature (˚C)
ta: Dry bulb temperature (˚C)

- **RayMan calculation software**

Data Verification

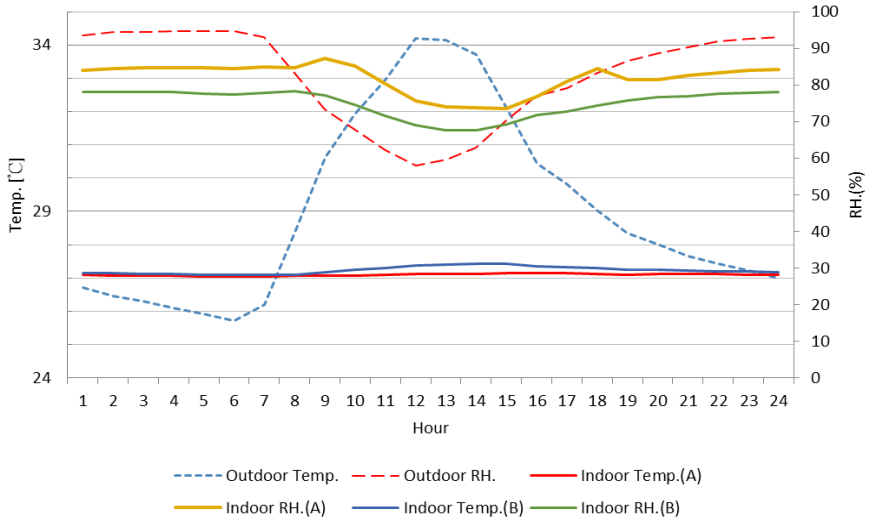
To confirm that the research data of the four case studies **can be compared and analyzed against each other.** In the control chart drawn using the residual values of temperature and humidity during hot season and cool season, values primarily falls within the control chart of the -3/+3 standard deviation range.

Physical Environment Measurement

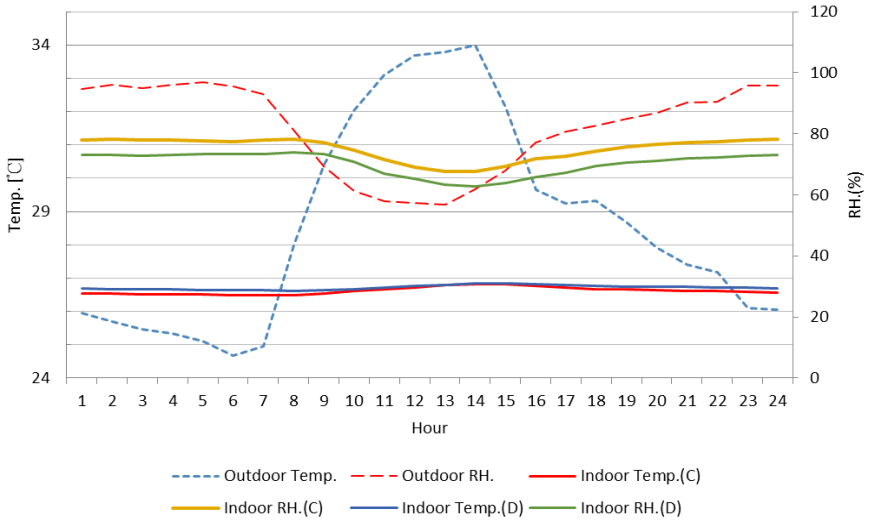
Actual Measurement Points	Case A Liushizongci	Case B Guangyuizhutang	Case C Wanchengzhutang	Case D Hexinghuofang
Direction of the building's primary opening	W-E	N-S	NNE-SSSW	NNE-SSSW
Measurement of the direction of the space's opening	N-S	W-E	ESE-WNW	ESE-WNW
Building plan				

N.B. Outdoor observation station is marked red points; indoor observation station is marked black points. The direction of building's opening is according to the direction the door faces; the direction it rests on is the sitting direction.

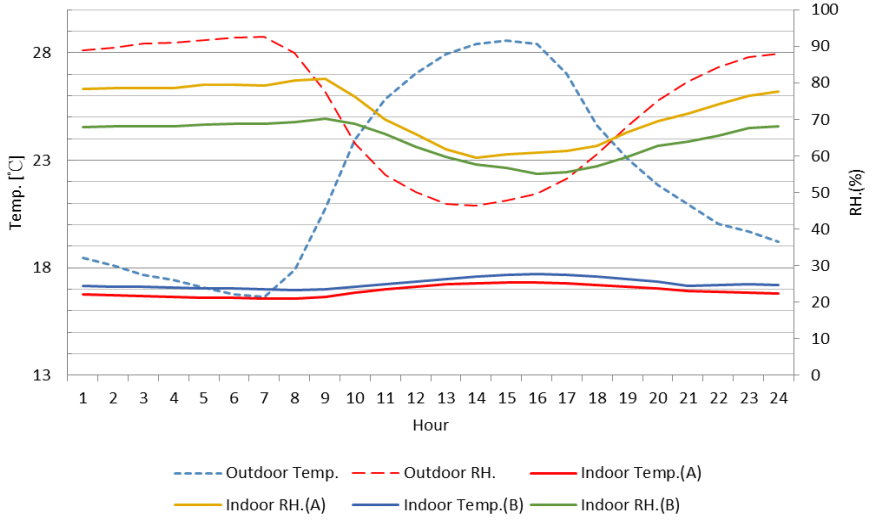
Average Indoor and Outdoor Data of Observed Local Historical Buildings (2014 - 2015)



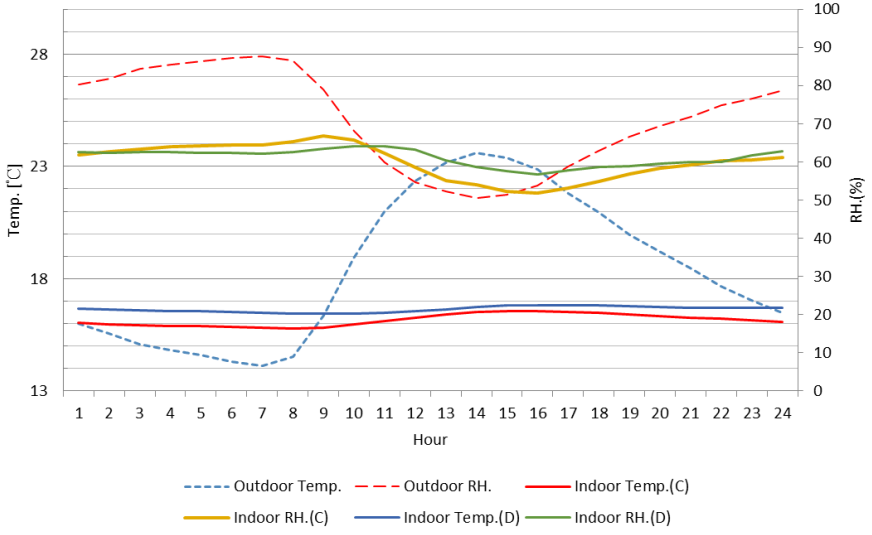
Case A and B in hot season



Case C and D in hot season

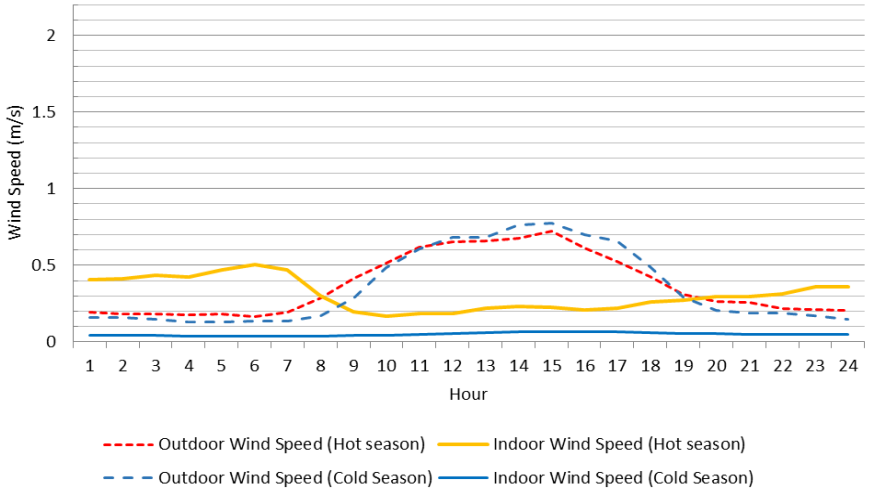


Case A and B in cool season

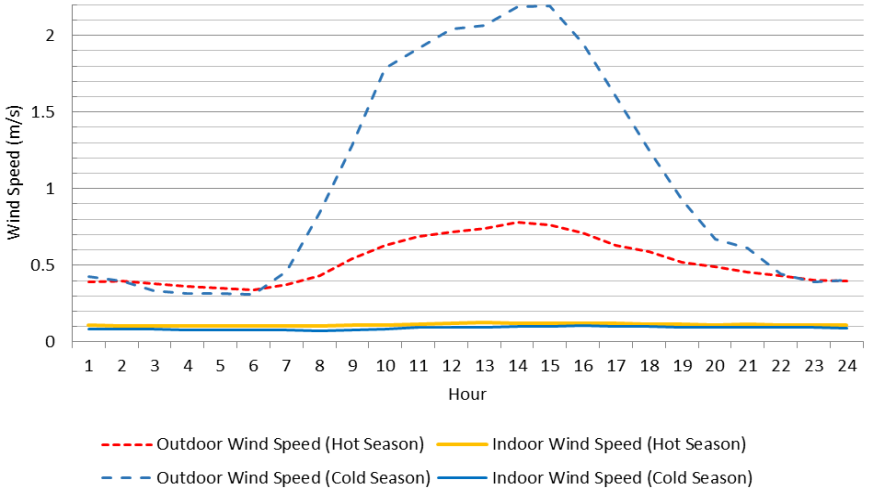


Case C and D in cool season

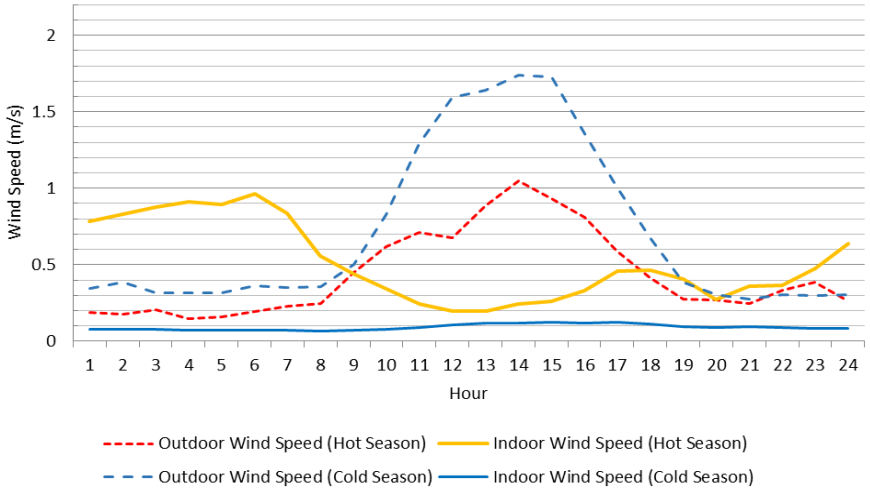
Average Indoor and Outdoor Wind Speed Data of Observed Local Historical Buildings (2014 - 2015)



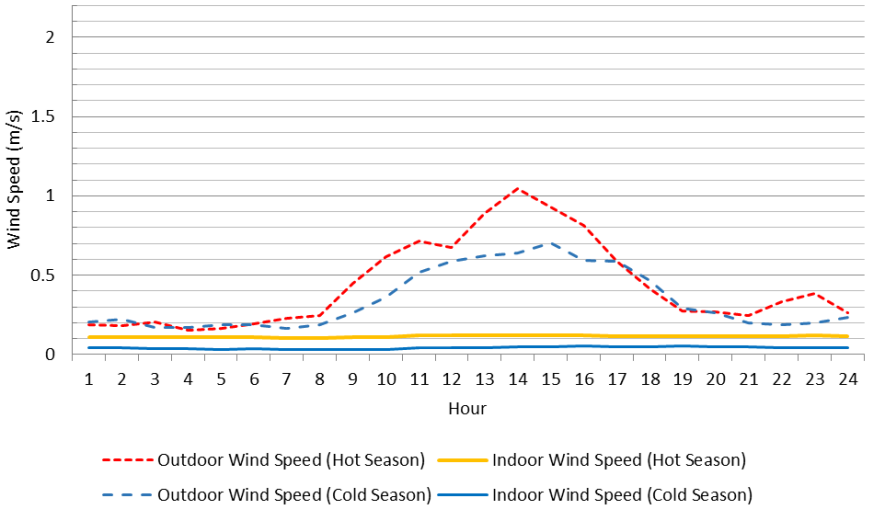
Case A



Case B



Case C



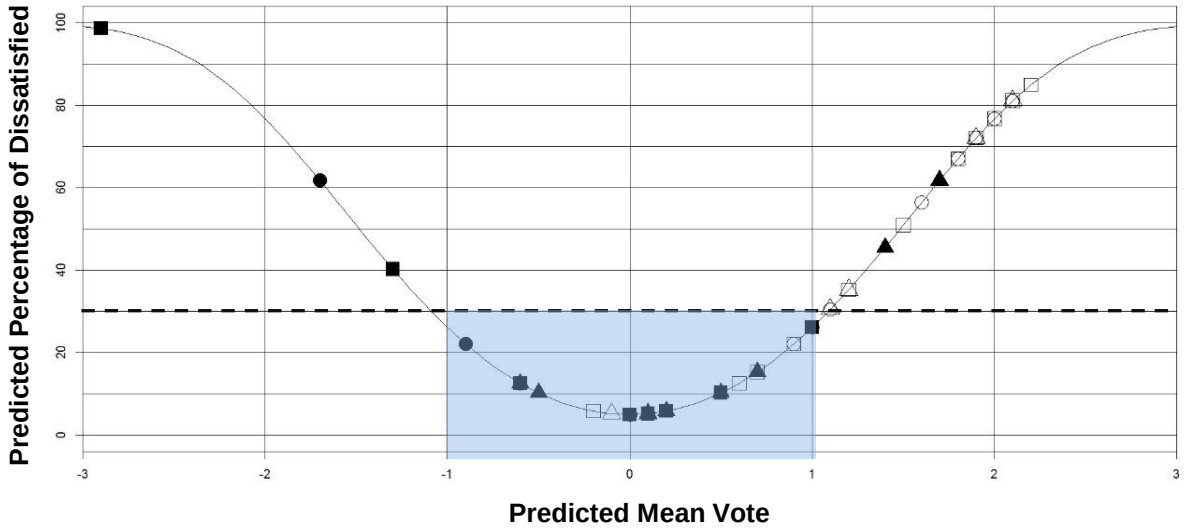
Case D

Analysis of Thermal Comfort

- **PMV and TSV Analysis**

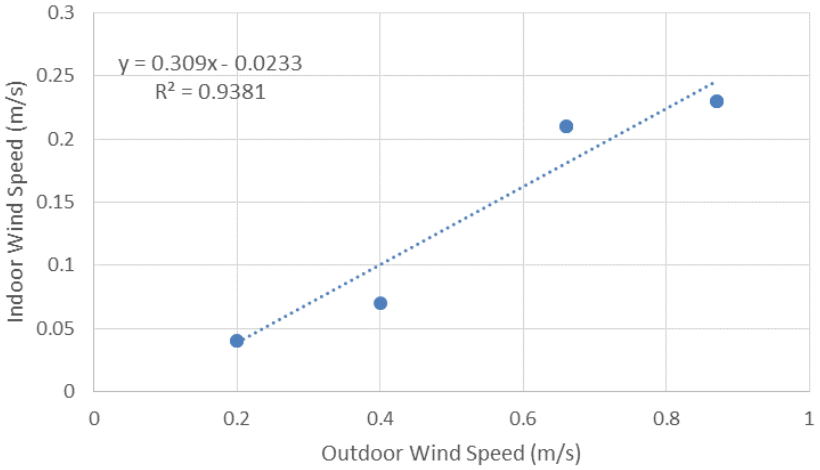
Item Analysis	PMV		TSV	
PMV=0 / TSV=0 Neutral Temperature (˚C)	25.9˚C (Hot season)		**28.64˚C** (Hot season)	
	22.5˚C (cool season)		22.3˚C (cool season)	
Comfort Zone (˚C)	27.93~30.38˚C (Hot season)	**32.43%**	27.93~31˚C (Hot season)	75.76%
	20.36~24.59˚C (cool season)	**75%**	**16.51~26.97˚C**(cool season)	91.67%
Thermal Acceptability (%)	---		**81.82% (Hot season)**	
			100% (cool season)	

- **PMV - PPD**

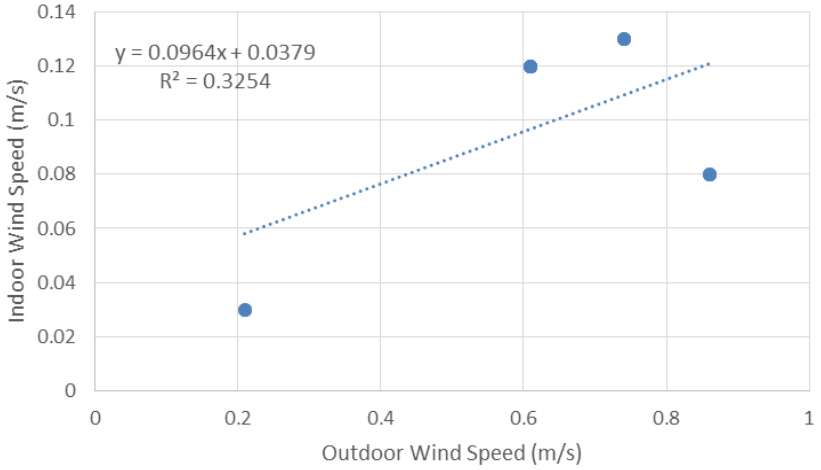


Analysis of Thermal Comfort

- **Wind Speed and PMV**
  - Based on the abovementioned analysis, noontime during the hot season is the time period that needs the most improvement.
  - The study uses linear regression to look at the outdoor and indoor wind speed by the presence and absence of openings; it finds that the two of The windows of the cases do not close are very much interrelated, with a relevant coefficient of R^2 = 0.9381.
  - Indoor wind speed can be strengthened to within **the 0.3 - 5.6 m/s range**, average wind speed increases **to 3.42 m/s, successfully reducing PMV values to within the comfort zone.**



The windows of the cases do not close



Windows of the cases can be opened and closed at will.

Conclusion

1. Building Opening

The study finds that factors influencing the level of indoor thermal comfort in historical buildings, in the order of level of influence, are **the building opening**, **building type**, and **building orientation and position**.

2. Humidity: Key Factor

Looking at the PMV and TSV**, humidity levels of hot and cool seasons in the locality are exceedingly high**; even if the hot environment is within the comfort zone during the cool season, close to one-half of the residents still feel uncomfortable.

3. Resident's Tolerance for Heat

When interviewees experienced slight environmental discomfort, they are still able to accept the environment; **this means the residents have a certain tolerance for heat**.

4. Wind Speed

During the hottest time period of the hot season, **average indoor wind speed increases to 3.42 m/s**, effectively reducing PMV values to within the comfort zone.

Thank you for your attention

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