Urban Heat Island (UHI) Micro-mapping via 3D City Model

Uznir Ujang, Suhaibah Azri, Maryam Zahir, Alias Abdul Rahman & Tan Liat Choon

Faculty of Built Environment and Surveying,
Universiti Teknologi Malaysia,
Johor, Malaysia.

Outline

- Urban Heat Island (UHI)
- Motivation
- 3D City Model
- Analyses:
  - Shadow Analysis
  - Solar Absorption Analysis
  - Orientation Analysis
- Conclusion

Urban Heat Island

- A city or metropolitan area that is significantly warmer than its surrounding rural areas
- Factor of UHI (reducing urban heat islands: compendium of strategies):
  - Less vegetation
  - Urban material properties
  - Urban geometry

Motivation

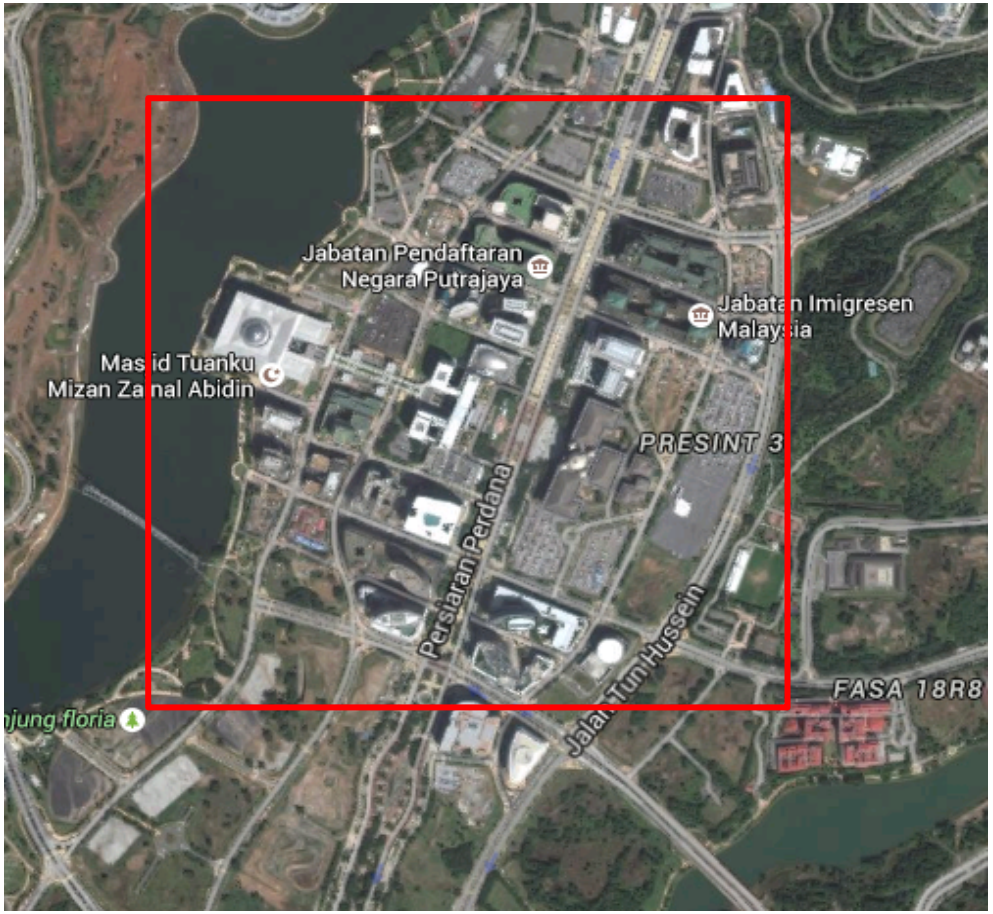
- What contributes to **UHI phenomenon**?
- How to **map UHI** (based on urban building design)?
- How **3D city modeling** can contribute to UHI mapping (in the view of urban building design)?
- **3D UHI map** using **3D city model** as a tool for efficient and sustainable building design.

3D City Model in UHI

- 3D building representation is **necessary** to understand how **urban geometry effects the UHI.**
- Many UHI researches relied on **2D information**, such as building footprints and land uses and hardly considering real-world 3D physical elements.
- It is hard to investigate complex urban characteristics that influence local climate without 3D information.

Research Scope

- Shadow analysis
- Precint 3 – Putrajaya



Research Scope

- Solar absorption and orientation analysis
- One building – “Palace of Justice”

Tools (Software)

- Autodesk Ecotect Analysis 2011
  - Helps in the design of a more energy efficient building
  - 3D modeling interface with import options such as 3DS and DXF

- ArcGIS 10.2.1
  - Geodatabase
  - ArcScene - ability to link 3D model with geodatabase
  - Heat analysis

Analysis 1: Shadow Analysis

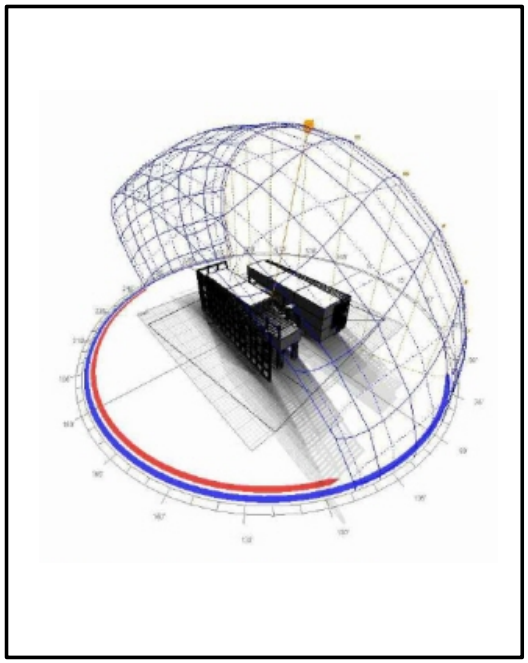
Model → Simulate → Visualize

Import model

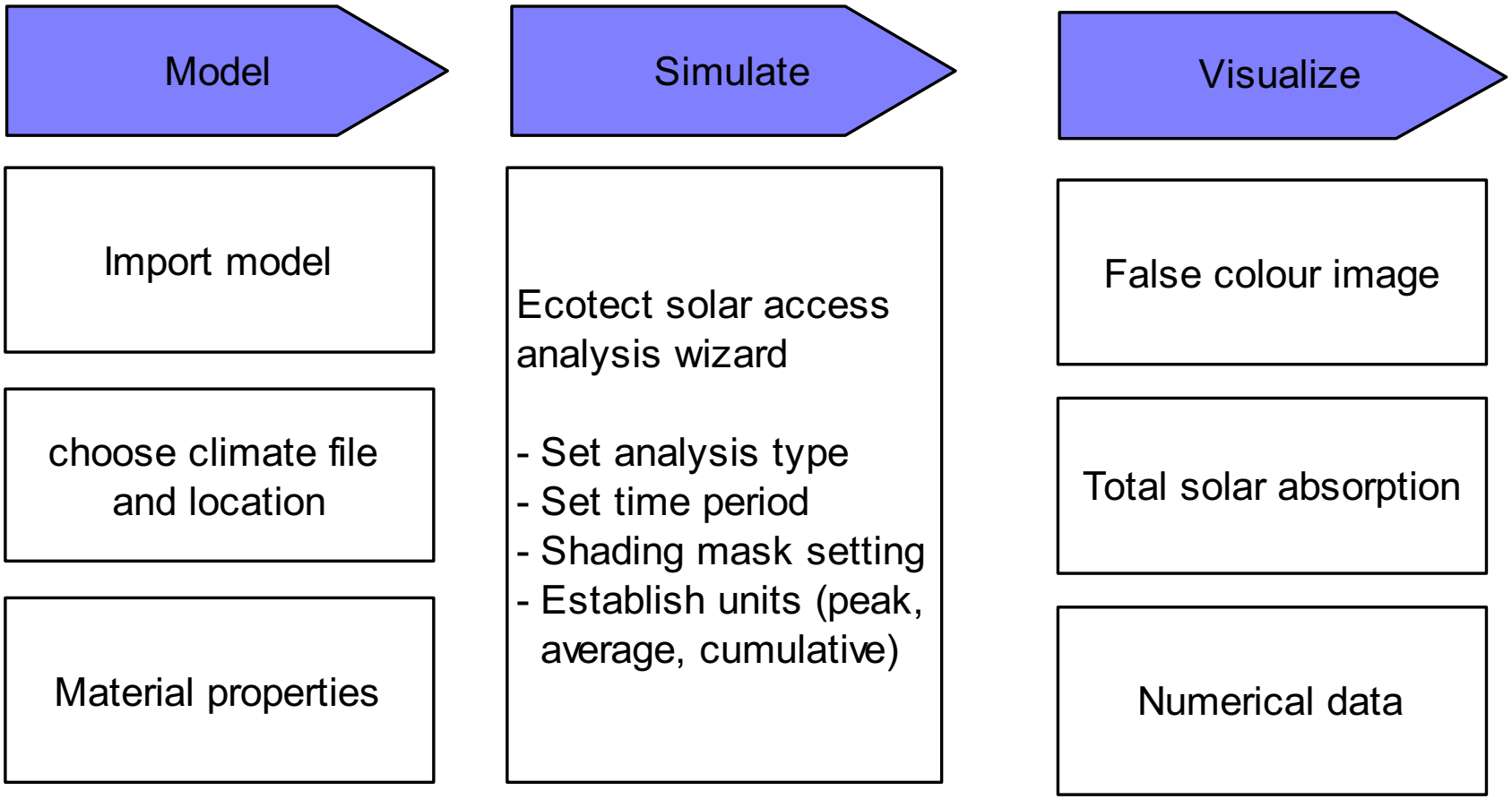
Set location
- dictates latitude, longitude, and climate

Sun setting

- Visualize shadow
- Sunlight hour
- Shadow range



Analysis 2: Solar Absorption Analysis



Analysis 2: Solar Absorption Analysis

	Type of materials	Texture	Solar Absorption range (0-1)
Dome	Plaster, Heat retention foil, Ceramic tile		0.548235
Roof	Concrete, Asphalt		0.900000
Wall	Concrete, Block Plaster, Granite		0.506000

Table 1 : Palace of justice building properties

Analysis 2: Solar Absorption Analysis

REPORT: OBJECT ATTRIBUTES - ALL

Description: Lists attributes of objects in model.

Model: C:\Users\Admin\Desktop\poj\POJ.eco

Object Attributes

Object ID	Object Type	Orient. (°)	Tilt (°)	Area (m2)	Total Incident Radiation Wh/m2	Total Absorbed Radiation Wh/m2
0000	Roof	148.89	-50.72	0.000	144.466	11446.873
0001	Roof	148.89	-50.71	0.000	144.456	11446.117
0002	Roof	148.89	-52.79	0.000	146.284	11590.918
0003	Roof	148.89	-52.80	0.000	146.291	11591.494
0004	Roof	-31.11	-20.23	0.000	520.378	38007.750
0005	Roof	-31.11	-20.24	0.000	470.094	34749.289
0006	Roof	-16.11	-20.25	0.000	385.067	28838.275
0007	Roof	-16.10	-20.21	0.000	387.791	
0008	Roof	-1.10	-20.21	0.000	393.912	
0009	Roof	-1.11	-20.18	0.000	414.979	
0010	Roof	178.89	-52.80	0.000	146.292	11591.607
0011	Roof	178.88	-52.79	0.000	146.282	11590.802
0012	Roof	178.88	-50.70	0.000	144.450	11445.616
0013	Roof	178.90	-50.73	0.000	144.477	11447.750
0014	Roof	178.90	-48.68	0.000	142.587	11297.962
0015	Roof	178.89	-48.67	0.000	142.580	11297.455
0016	Roof	178.89	-46.60	0.000	140.601	11140.666
0017	Roof	178.90	-46.63	0.000	140.624	11142.475
0018	Roof	178.90	-44.59	0.000	138.595	10981.692
0019	Roof	178.89	-44.56	0.000	138.571	10979.794
0020	Roof	178.89	-42.48	0.000	136.429	10810.046
0021	Roof	178.89	-42.48	0.000	136.422	10809.505
0022	Roof	178.89	-40.49	0.000	134.302	10641.544
0023	Roof	178.88	-40.46	0.000	134.277	10639.544
0024	Roof	178.88	-38.38	0.000	131.990	10458.299
0025	Roof	178.88	-38.38	0.000	131.993	10458.587
0026	Roof	178.88	-36.34	0.000		
0027	Roof	178.89	-36.36	0.000		

Autodesk Ecotect

(Climate and location information)

Excel format (Output format)

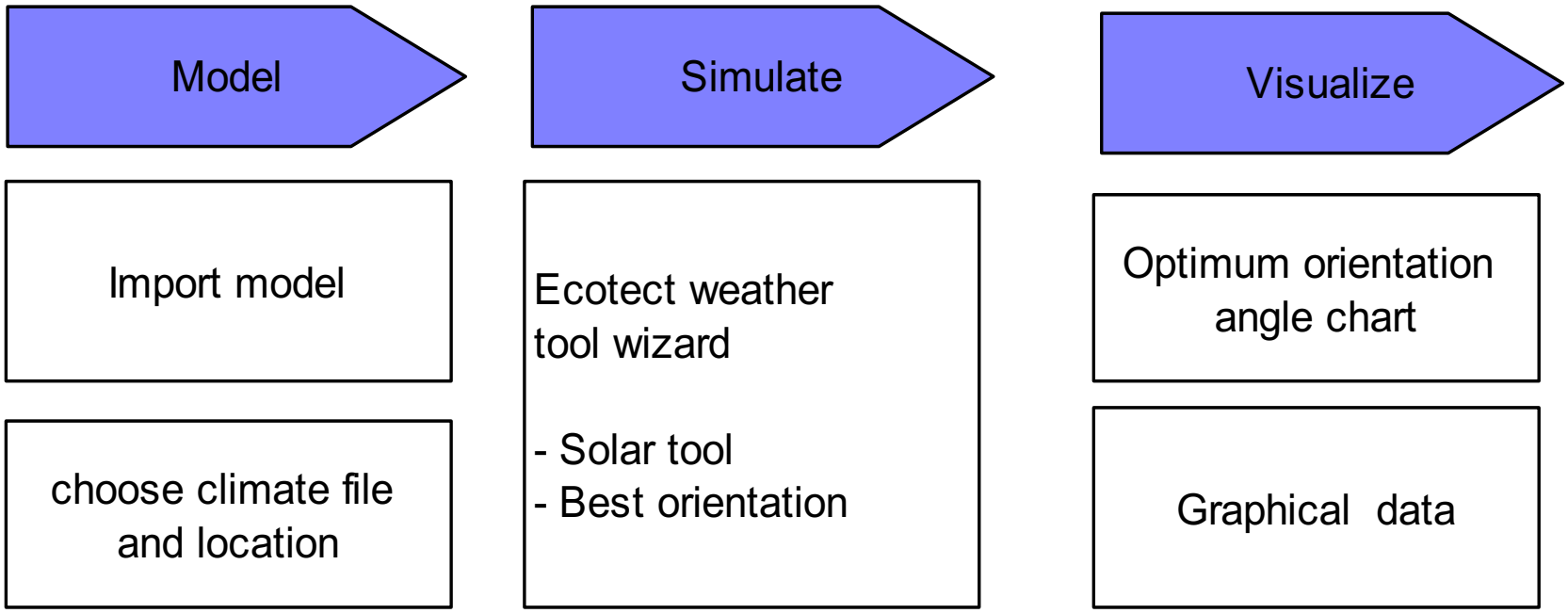
Object ID	Object Type	Object (ID)	Orient.(°)	Tilt(°)	Total Incident Radiation Wh/m2	Total Absorbed Radiation Wh/m2
0	Roof	1	111.39	-50.72	4490.943	347379.344
1	Roof	1	111.39	-50.71	4502.512	348274.094
2	Roof	1	111.39	-52.79	4545.021	351562.406
3	Roof	1	111.39	-52.8	4553.471	352215.969
4	Roof	1	-68.61	-20.23	16498.121	1219852.75
5	Roof	1	-68.61	-20.24	16437.533	1220982.875
6	Roof	1	-53.61	-20.25	16585.582	1215582.125
7	Roof	1	-53.6	-20.21	16617.109	1217597.875
8	Roof	1	-38.6	-20.21	15681.85	1133372
9	Roof	1	-38.61	-20.18	15733.109	1128865.875
10	Roof	1	141.39	-52.8	4541.833	351315.625
11	Roof	1	141.38	-52.79	4544.763	351542.25
12	Roof	1	141.38	-50.7	4486.528	347037.656
13	Roof	1	141.4	-50.73	4499.823	348066.188
14	Roof	1	141.4	-48.68	4432.77	342879.562
15	Roof	1	141.39	-48.67	4455.517	344638.875
16	Roof	1	141.39	-46.6	4381.974	338950.406
17	Roof	1	141.4	-46.63	4397.51	340152.156
18	Roof	1	141.4	-44.59	4320.59	334202.156
19	Roof	1	141.39	-44.56	4340.923	335774.906
20	Roof	1	141.39	-42.48	4266.45	330014.25
21	Roof	1	141.39	-42.48	4281.614	331187.375

FID	Shape	Entity	Layer	Color	Linetype	Elevation
1	MultiPatch	3DPolyline	dome	1	Continuous	2033.334595
2	MultiPatch	3DPolyline	dome	1	Continuous	2041.169434
3	MultiPatch	3DPolyline	dome	1	Continuous	2041.169434
4	MultiPatch	3DPolyline	dome	1	Continuous	2048.653564
5	MultiPatch	3DPolyline	dome	1	Continuous	2048.653564
6	MultiPatch	3DPolyline	dome	1	Continuous	2055.996094
7	MultiPatch	3DPolyline	dome	1	Continuous	2048.653564
8	MultiPatch	3DPolyline	dome	1	Continuous	2055.996094
9	MultiPatch	3DPolyline	dome	1	Continuous	2055.996094
10	MultiPatch	3DPolyline	dome	1	Continuous	2048.653564
11	MultiPatch	3DPolyline	dome	1	Continuous	2048.653564
12	MultiPatch	3DPolyline	dome	1	Continuous	2041.169434
13	MultiPatch	3DPolyline	dome	1	Continuous	2041.169434
14	MultiPatch	3DPolyline	dome	1	Continuous	2033.334595
15	MultiPatch	3DPolyline	dome	1	Continuous	2033.334595
16	MultiPatch	3DPolyline	dome	1	Continuous	2025.159302
17	MultiPatch	3DPolyline	dome	1	Continuous	2025.159302
18	MultiPatch	3DPolyline	dome	1	Continuous	2016.653809
19	MultiPatch	3DPolyline	dome	1	Continuous	2016.653809
20	MultiPatch	3DPolyline	dome	1	Continuous	2007.829224
21	MultiPatch	3DPolyline	dome	1	Continuous	2007.829224
22	MultiPatch	3DPolyline	dome	1	Continuous	1998.696899

ArcGIS database

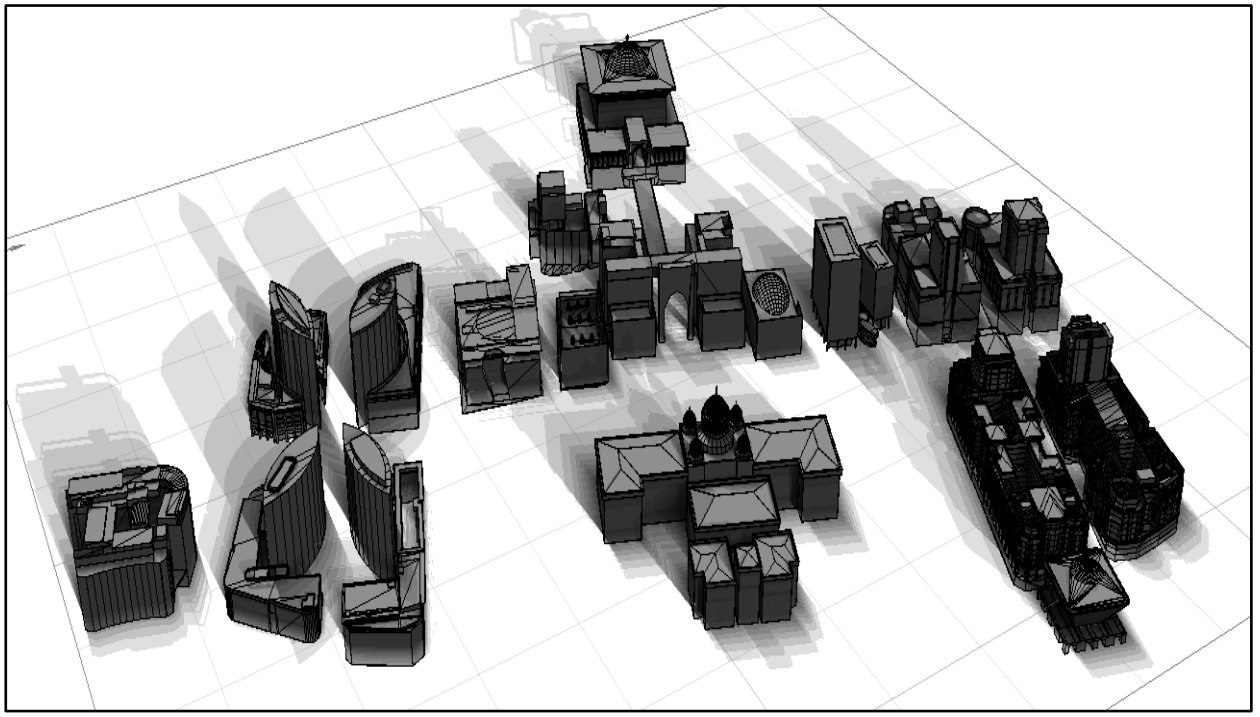
(GIS ready format)

Analysis 3: Orientation Analysis



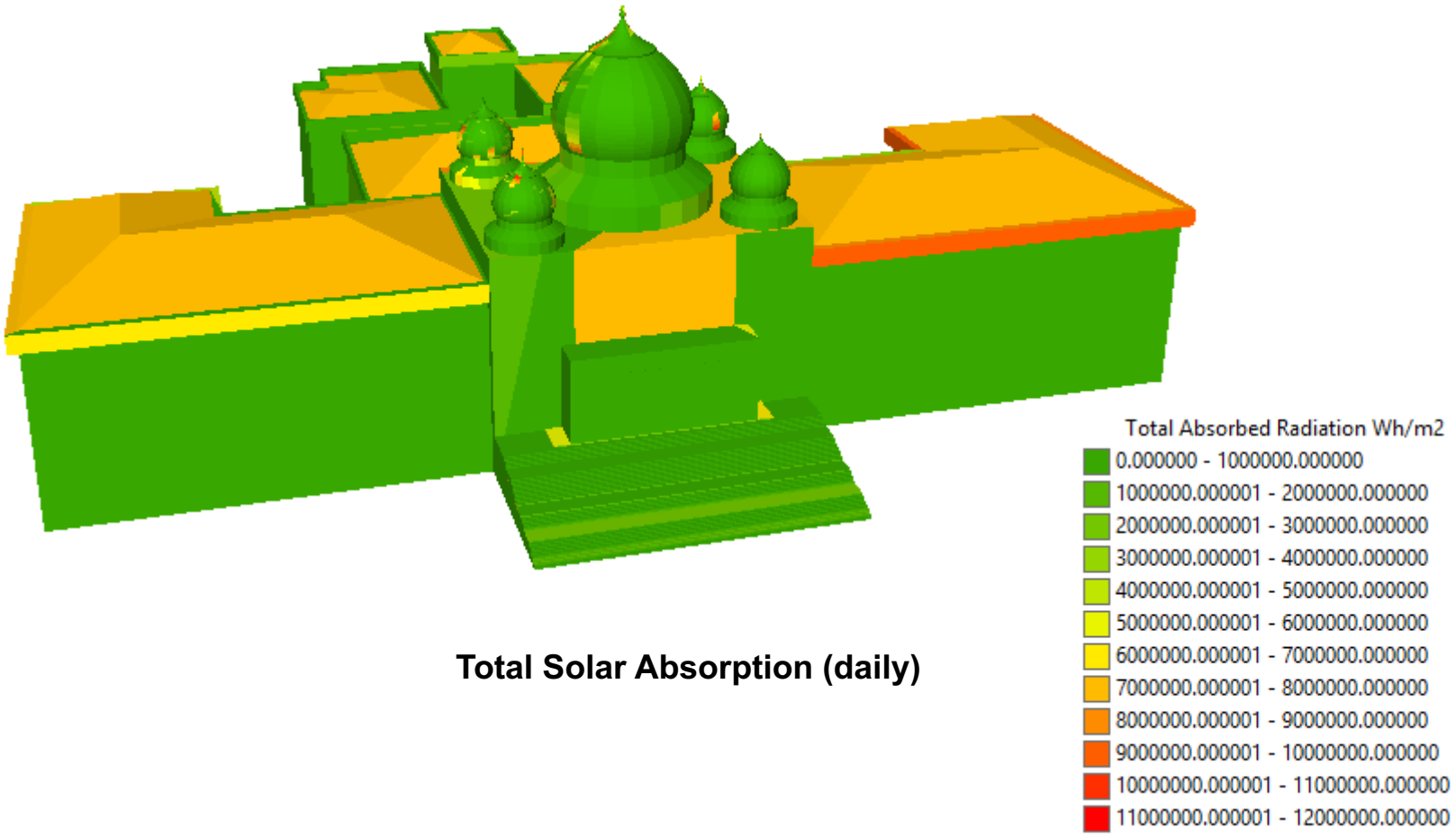
Shadow Analysis

- To view buildings that are not exposed to sunlight from different view angles at a particular time
- Shadow ranges based on certain times



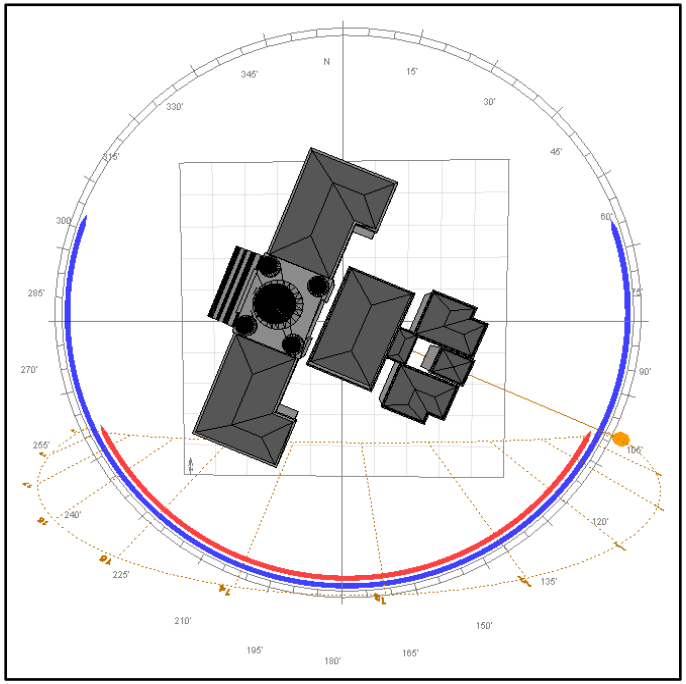
Shadow range from 0800-1700

Solar Absorption Analysis

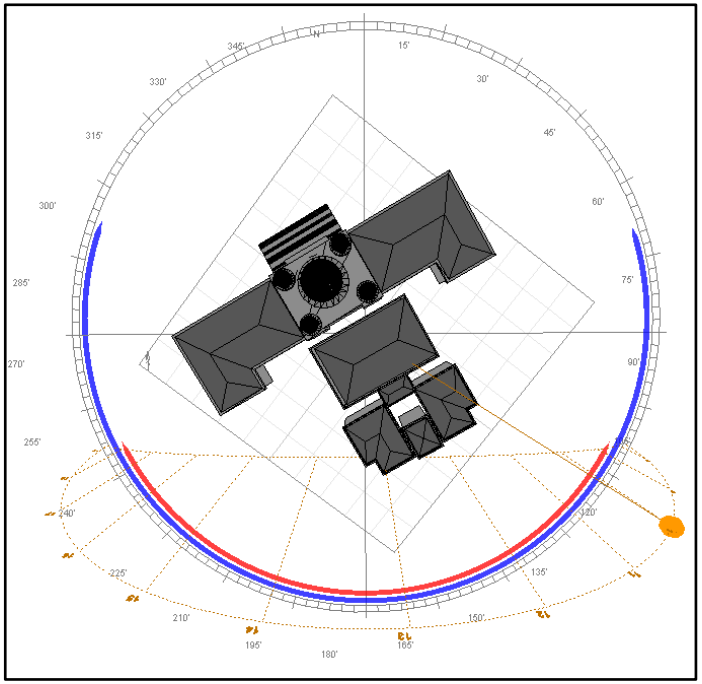


Total Solar Absorption (daily)

Orientation Analysis

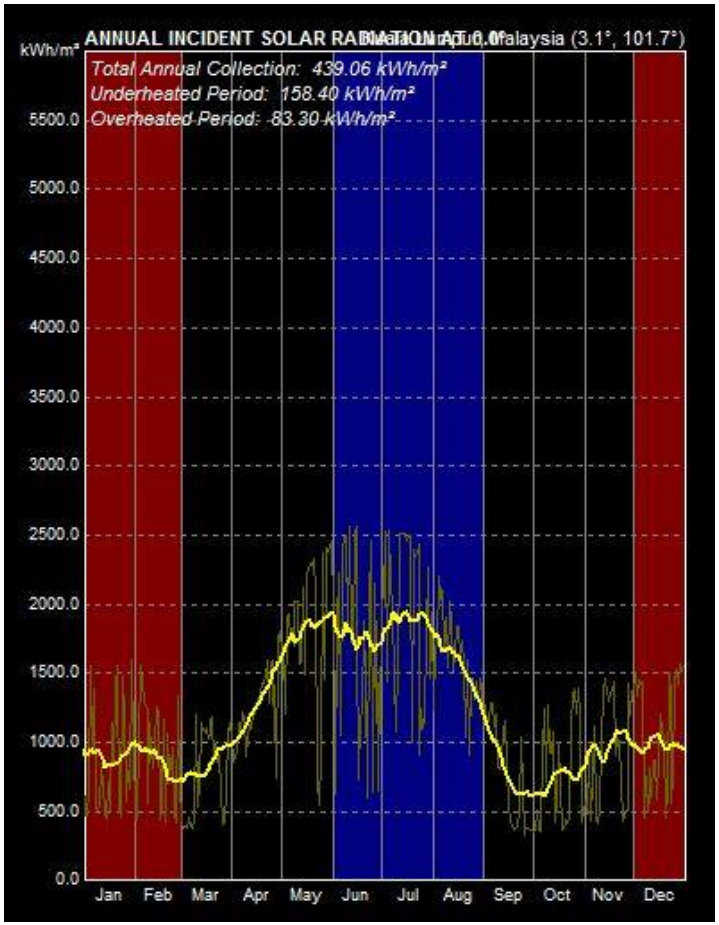


The original position of POJ building

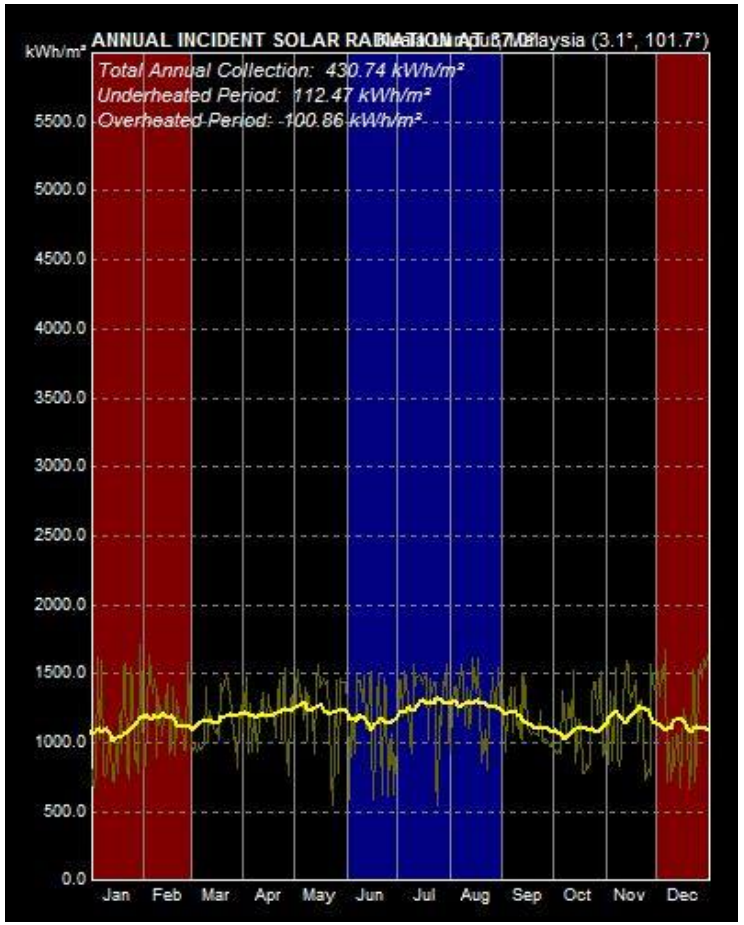


The position of POJ building after alteration of 37.5˚

Orientation Analysis



Annual incident solar radiation for building in original position



Annual incident solar radiation for building after alteration

Conclusion

- Urban building design does influence the temperature of a building.
- The approach could be utilised for early phase of city development planning.
- UHI models may help to simulate the environmental impacts due to changes in urban infrastructure.
- Other factors to consider – colour, shape, wall thickness, materials, etc.

UTM
UNIVERSITI TEKNOLOGI MALAYSIA

Thank you

alias@utm.my