Decision Support System: User research, usability analysis and computational build

Report

Author(s):
Chan, Michelle; Ye, Cong; Perhac, Jan

Publication date:
2020-09-30

Permanent link:
https://doi.org/10.3929/ethz-b-000450016

Originally published in:
Technical Report D 4.2.2

DELIVERABLE

TECHNICAL REPORT

Version 30/09/2020

D4.2.2 – Decision Support System: User research, usability analysis and computational build

Project ID	NRF2019VSG-UCD-001
Project Title	Cooling Singapore 1.5: Decision Support System – User Research, Usability Analysis and Computational Build
Deliverable ID	D4.2.2 – Decision Support System: User research, usability analysis and computational build
Authors	Michelle Chan Mei Har, Cong Ye, Jan Perhac
DOI (ETH Collection)	
Date of Report	30/09/2020

Version	Date	Modifications	Reviewed by
1	30/09/2020	Original	Jan Perhac, Lea A. Ruefenacht, Ido Nevat

CS
COOLING SINGAPORE

NATIONAL RESEARCH FOUNDATION · CREATE · (SEC) SINGAPORE-ETH CENTRE · SMART · TUMCREATE · SMU · NUS · Agency for Science, Technology and Research

1 Abstract

This technical paper summarises the research and usability tests done for the '**D**ecision **S**upport **S**ystem' (DSS) interface in its second iteration. The purpose is to improve the DSS user experience and its analysing and visualising capabilities. The DSS platform allows users to assess urban design scenarios in a systematic and interactive way. It not only visualizes data input, but also facilitates data analysis, multiple comparisons and accord recommendations based on selections set by the user, hence a decision support system. The DSS platform aims to be a dynamic visualisation platform, an interface that is user-centred, effective in its computational capabilities and an aide in bringing research data to the forefront of an informed decision.

This second iteration stems from its predecessor[1] first done based on its original build, Singapore Views[2] conducted in the months of October and November of 2019. The previous research approach was a general one, in which the users studied were from a wide range of backgrounds and are users who may or may not have been exposed to the Singapore Views platform. The creation of the DSS prototype one was based on these first set of examination and usability test findings. Concurrently, the focus at this stage was re-centred to the studies of the Outdoor Thermal Comfort (OTC) of Singapore. Thus, the users previously established had to be further investigated and cater to their specific needs. These group of users are from both government agencies and academic institutions (*e.g.*, the Cooling Singapore 1.5 scientific team). This re-establishment was carried out through another cycle of in-depth qualitative/quantitative survey and usability test on prototype one conducted in the months of February and March of 2020. We later feature prioritise the list of findings based on the criterions of necessity, impact, time constraint and feasibility. Features upon approval of the team would then proceed into prototype two.

[1] *User Research: Decision Support System Interface Development Through Personas - (Michelle Chan, 2020) https://doi.org/10.3929/ethz-b-000406489*

[2] *Singapore Views - Developed by Dr. Jan PERHAC at Collaborative Interactive Visualisation and Analysis Laboratory (CIVAL), Singapore-ETH Future Cities Laboratory.*

Table of Content

2 Introduction

2.1 Background

An earlier research was done in part to inform the 'decision support system' development. The research was carried out in both qualitative and quantitative methods and the resultant outcomes were of persona(s) and an interface creation. The findings show that there were of 3 generic persona(s). The press/public, the researcher/planners and the consultant/upper management persona(s) respectively. However, for this continued effort in iteration two, the users have been re-centred to focus on the populace from the scientific team and planning group (this includes various government agencies). This populace did not include the public users, therefore one of the aforementioned persona(s) of press/ public cannot be validated.

The users in this second iteration all have different expertise, priorities and objectives. It is apparent as later found, the user(s) respective tasks have research topics and analysis outputs that are closely linked. These tasks revolve around the investigation of anthropogenic heat impact, the Outdoor Thermal Comfort (OTC) experienced by people on a district level and the different models that help in the study of these effects. The model outcomes are then extrapolated and applied to an even greater scale. It is ultimately a study that weighs in on the varying effects of heat produced by human activities, the potential solutions to mitigate these consequential temperatures, benefits/losses from these solutions and how to manage the OTC levels experienced by humans at present and the near future.

2.2 Objectives

The objective is to improve the '**D**ecision **S**upport **S**ystem's' (DSS) user experience and its analysing, visualising capabilities. The deliverables are to craft a user interface for the DSS that is effective and user-centred.

2.3 Hypothesis

We believe that by conducting iterative quantitative/qualitative research and usability tests with the actual users of DSS, we will gain better insights of the user needs, expectations and habits. We can also better understand the platform's effectiveness and have clearer insight into its improvements. We will know this hypothesis to be true when we see an increase in the number of users and a high success rate in understanding the data analysed. The success value is measured and validated through user and system/platform analysis.

3 Methods

3.1 Preparation

The following three types of research efforts were conducted:

1) *User survey (online question and answer)*
   This step aims to discover the users' objectives, their approach to research/analyse, their final deliverables and aspired needs.

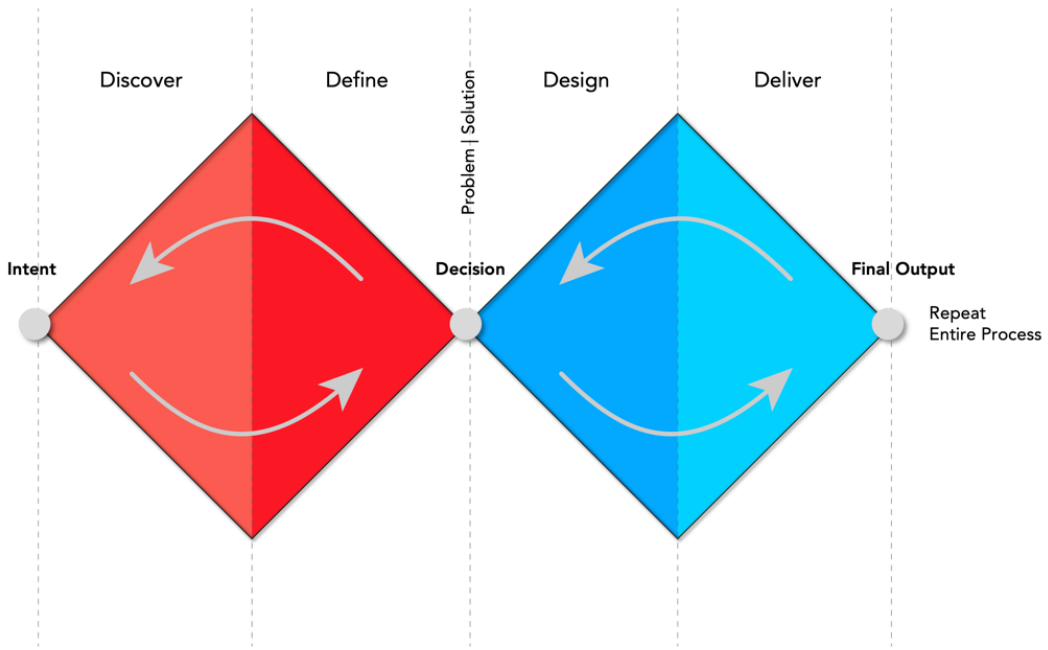
2) *Prototype one usability test (recorded screen video)*
   This step allows us to gather evidence and to observe users' usage of the DSS platform. Additionally, it helps to verify the platforms effectiveness, understand user norms/habits and detect possible counter-intuitive aspects.

3) *Single Ease Questions (SEQ) [multiple choice question and short question answer]*
   This step helps to retrieve experiential feedback of usage, verify recorded problem areas seen from user usability test, understand their expectations and invite suggestions to potential improvements.

3.2 Design of the experiment/ modelling

Generally, most user experience processes or design thinking approaches are the same at their core. The process starts off with a framework to tackle the project objectives through research prior to the execution. A study is conducted into all aspects of the product, analysis of the different issues, design the solutions, test the prototype and iterate the whole cycle again. This cyclic process rarely ceases, as any good development is progressive and is always striving for improvement. The more informed the research and tests are, the more accurate the solve. It is precisely with this same simple idea that the Double Diamond[3] (Diagram) was chosen. It is essentially a divergent and convergent framework that encourages wide explorations and then take focused action. The double diamond methodology consists of 4 phases in which each phase is iterative to each other: “Discover, Define, Design and Deliver”.

Diagram 1



[3] *Double Diamond is the name of a design process model popularized by the British Design Council in 2005, and adapted from the divergence-convergence model proposed in (1996) by Bela Banathy.*

3.3 Experiment

As this is the second iteration, we already had a basis to build further on. To start off the second iteration, we further studied these focused users of the DSS platform. An online survey was created to discover in greater depth the user archetypes from within the pool targeted. The pool of users that the survey was open to were predominately from the Cooling Singapore scientific team and planning group that it works closely with. The research team comprised members of various levels. Namely, the principal investigators, planners and researchers of various fields. The intent was to investigate their process, expectations and requirements when researching and analysing comparison outcomes of various data sets. Their respective outlook varies depending on their range of concern in which you may discover later in the report whereby some of their interest areas and feedback overlap. In others, users provided varied insights as to where we can further explore or develop. We would know this investigation to be effective and is indeed on route to continuous improvement through an iterative process of user research and usability tests with actual users of the system.

The usability test is set in three parts with sub-sections investigating different aspects of the prototype. Part one is familiarization of the interface and understanding the user needs. In familiarization, we refer to investigating whether the user(s) understand what the tools presented on the interface do, the manoeuvring within the workspace and the user's comfort level. Part two is the actual usability task set. This is to investigate the interface's intuitiveness, the pain points user(s) experience while using the tool, whether the data visualised is well understood and to better understand the expectations of the user's objectives. Part three is an open study of user's interests and preferences. User(s) were not briefed prior on the tasks or what the interface would contain. After user impressions were collected, the user(s) were then introduced to the functions of the system. All users were encouraged liberally to feedback the conventions they are accustomed to when operating software of various varieties and express their personal thoughts across all sections of the test. This was to gather the general consensus of how they analyse data and the habits of these users. User(s) are of varying level of technological savviness and had different experience levels with the DSS platform. All participants have awarded the study permission to record their usability tests and respective survey responses.

After all responses have been analysed, a process of feature prioritization was conducted. The end product of this feature prioritization is a list of features that is approved by the team and deemed achievable in the next iteration. Prototype two is then built with aspects of proof-of-concept and various challenges. The final output would be an effective DSS prototype that is user(s) informed. As part of the iterative process, a usability workshop was conducted at the end of September 2020 to collect feedback on prototype two.

4 Results

4.1 Deliverables

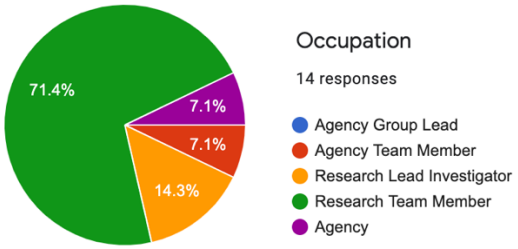
Item	Content	Participants
User Survey	Overall statistical summary and 14 individual outcomes of online user research	Total 14 respondents: 2 government personnel, 12 Cooling Singapore researchers of mixed levels
Usability Test	15 screen recordings of users on DSS platform performing usability tasks	Total 15 users: 3 government personnel, 12 Cooling Singapore researchers of mixed levels
Single Ease Questions (SEQ)	15 Scanned feedback print outs with responses and feedbacks/suggestions	Same users as usability test recordings (above)

4.2 User Survey[4] Analysis

The following are questions posed to the users with its corresponding quantitative/qualitative feedbacks. The findings are in a list format of which similar ones are collapsed as a single point. The summary are drawn and inferred from these responses. Total respondents: 14 (2 Agencies | 2 Senior Researchers | 10 Team Researchers).

Question 2 and 3: User to fill in occupation and organisation (respectively)

Participants' feedback:



0%	Agency Group Lead (0)
7.1%	Agency Team Member (1)
14.3%	Research Lead Investigator (2)
71.4%	Research Team Member (10)
7.1%	Others – labelled as "Agency" (1)

Summary:

The survey had a response that intentionally chose "agency" in the 'other' category as it was answered as team. They decidedly chose to represent themselves as a collective of agency leads and members and not as a single user in the other options. From the statistics, we can validate that the two persona(s) researcher/planner and upper management found in the earlier research is true and is still present. Another find is the identification of sub-persona(s), in which both persona(s) have varied occupational stations differentiated by seniority.

Question 5, 6: "Area of research" and "I am tasked to…" (respectively)

Participants' feedback:

- Understand how different features like geometry, paint, anthropogenic heat contribute to the Urban Heat Island (UHI) effect and how to mitigate it in the most cost-effective way.
- Carry out environmental what-if scenario modelling and support Urban Heat Island/ Outdoor Thermal Comfort (OTC) mitigation strategies.
- Determine the effects of anthropogenic heat of energy systems, buildings and transportation to the surrounding environment temperatures in both mesoscale and microscales.
- Develop urban design guidelines that are climate sensitive based on research derived analysis and impact.

4 User Survey - Blank survey can be found at the end of this document in glossary.

- Develop a map/visualisation tool that encompasses the social, geographical and climatic parameters of the country for analysis that aid decision making by policy makers.
- Discover surface temperature in various areas of the country and also validate the Weather Research and Forecasting (WRF) model.
- Develop knowledge and understanding of UHI phenomena and analyse the impact of the different OTC strategies.
- Analyse the workflow of researches and develop a digital platform where results of these researches can be optimised for non-expert users in their application onto their own evaluation of UHI and OTC.
- Measure and analyse the impact of UHI in a social-economical context. With regards to three aspects. (Willingness to pay) – preferences to mitigation strategies, awareness of climate change. (Cognitive performance of older adults) – to analyse and to what extent do the vulnerable populace would be most compromised by the heat and humidity exposure. (Cost-benefits) – the cost analysis on selected mitigation strategies.
- Conduct UHI simulations on a mesoscale and analyse its impact of wind and vegetation on a microscale.
- Analyse and propose interventions that would increase energy efficiencies, hence a UHI reduction.

Summary:

We can see from the list of varied research objectives and area of research, user(s) found in the populace are experts in different specialised disciplines. The scope covered by the user(s) also varies. Some user(s) of seniority focus more on the overall objectives of the study, whereas team members concentrate more on the technical aspects and an in-depth understanding of their specific studies. Generally, all user(s) are concerned or are contributing partners to the analysis of OTC mitigation strategies, its effects, how it affects other conditions and the creation of models that can mimic these circumstances.

Question 7: *"We retrieve our information from..."*

Participants' feedback:

- Most of the data developed are in-house and consolidated through Geographic Information System (GIS).
- User mentioned that their data are from public domains like the Meteorological Service Singapore (MSS) or their internal databases. The purpose is to simulate how different scenarios affect OTC. To visualise how they perform under different environmental factors.

- Data are from Non-Disclosure Agreement (NDA) data sets, public domain data sets and Cooling Singapore commissioned sensor data. They are used to infer different spatial and temporal climatic behaviour.
- Data are from literature reviews, Singapore government bodies like National Environment Agency (NEA) and Urban Redevelopment Authority (URA) provided resource. Some of these data are clustered and used as boundary conditions to run simulations (weather type). Others are urban indices for scenario geometry (urban density, gross floor area). Users evaluate urban design impact using physiological equivalent temperature (PET) and other climatic variables as a parameter indicator.
- Official documents by Singapore's electricity market and stakeholders in the electricity market.
- Data provided by Land Transport Authority (LTA) and open source data (e.g., google maps, open street maps).
- Data are from open source authorities and various types of sensors deployed to take readings and measurements for different OTC scenarios.
- User mentioned they retrieve the information by conducting interviews with different researchers and understanding their process, a workflow is created which serves as a blueprint for an eventual automation platform of these workflows.
- Literature reviews and estimated historical data.
- Global data sets, satellites and local observatories Light Detection and Ranging (LIDAR).
- Data sets from Singapore department of statistics, MSS, open source data, simulations with numerical/ Computational Fluid Dynamics (CFD) models and on-site measurements from weather stations.
- Data on energy consumption from buildings that are open source. Weather data are from weather stations. Buildings interventions are modelled from Building Energy Models. (BEM)

Summary:

From the list of resources seen, we can identify that the user(s) mostly obtain their data from government agencies, actual commissioned measurements, public domains and from academic literature. In knowing where the user(s) retrieve their information, we can better anticipate the variety of incoming data and the potential visualisation needed to display their data analysis.

Question 8: *"Analysis: Using all these information, we compare by..."*

Participants' feedback:

- Simulating different scenarios and reviewing their effects.
- Running simulations of the study area with various scenarios with climatic variables and cross-compare the outcomes with a baseline to determine how each output performs.
- Creating a vulnerability map with demographic information. Integrate adaptive and sensitivity indicators to the hazard context (spatial distribution of temperature over demographic vulnerability).
- Based on data gathered, we make an astute estimate of power generated per end-use or mid-stream sectors. Understand the breakdown of the power production, their efficiencies and when.
- Discover the amount of heat that gets released from unconverted energy fuels.
- Using information gathered, run simulation models to compare the heat emissions in the current scenario and future possible ones.
- Using data gathered from simulation models and actual measurements, we compare and analyse the result spatially and temporally for their respective UHI and OTC performance.
- Understanding the complicated process required to produce the simulations of various forms well, how it can be then made efficient by a computational build, simplifying the process and then automate it.
- Performing statistics and econometric analysis on data collected, hypotheses and models that are built and tested by formal analysis (willingness to pay).
- Experimental designed data would be analysed relatively to statistical test and regression analysis (cognitive performance of older adults).
- For behavioural analysis, determinants are evaluated by a particular behaviour formulated by a designed questionnaire which captures demographic, lifestyle attitudes, preferences and social economic characteristics.
- Data from MSS is used as input to run CFD simulations, buildings are extracted from open street map and the on-site measurements are used to validate the simulations results.
- Using weather data as an input for BEM simulation which outputs energy consumption. It is then compared to metered data. The data is then calibrated and validation is adopted to reduce input uncertainties and to verify confidence of the models.

Summary:

From understanding how the user(s) analyse their data and with what tools/ methods, we can better determine what tools the platform should also include or may need to develop. Given that some of the different studies may have similar objectives or units, they may not share the same meaning. In understanding the data that is provided by the user(s) and how user(s) analyse, we can help interconnect all data and build each study upon each other. Creating an overarching story that communicates a holistic visualisation and analytic study.

Question 9: *"Most of them are…"*

Participants' feedback:

- Energy units in kWh and joules.
- Vtk[5] files, Csv[6] files in temporal and spatial resolution.
- Temperature (°C), Wind speed (m/s), Relative humidity (%), PET (°C), Mean Radiant Temperature (°C), Surface Temperature (°C), Solar Heat Flux, Solar Radiance (W/m^2), Anthropogenic Heat Flux (W/m^2).
- Shp[7] and raster[8] files in both temporal and spatial resolution.
- Usu[9] tabular data in a time series.
- Kilotonne of oil equivalent (ktoe).
- Tiff[10], png[11], dwg[12] and NetCDF[13].

5 Visualization Toolkit (VTK) is an open-source software system for 3D computer graphics, image processing and visualization.

6 CSV is a comma-separated values file, which allows data to be saved in a tabular format.

7 SHP is a file extension for a Shapefile shape format used in geographical information systems (GIS) software. SHP is short for "shape." A shape file contains geographical reference data as individual objects such as a street, a river, a landmark or a zip code area.

8 A raster graphic, such as a gif or jpeg, is an array of pixels of various colours, which together form an image.

9 Usu files are Tabular data is data that is structured into rows, each of which contains information about some thing. (...) This specification refers to such files, as well as tab-delimited files, fixed field formats, spreadsheets, HTML tables, and SQL dumps as tabular data files.

10 Tagged Image File Format, abbreviated TIFF or TIF, is a computer file format for storing raster graphics images, popular among graphic artists, the publishing industry and photographers.

11 A PNG file is an image saved in the Portable Network Graphic (PNG) format, it is commonly used to store web graphics, digital photographs, and images with transparent backgrounds.

12 DWG (from drawing) is a proprietary owned binary file format used for storing two- and three- dimensional design data and metadata.

13 (NetCDF network Common Data Form) is a file format for storing multidimensional scientific data (variables) such as temperature, humidity, pressure, wind speed, and direction. Each of these variables can be displayed through a dimension (such as time) in ArcGIS by making a layer or table view from the netCDF file.

- Stl[14], Cxf[15], xslx[16] format and additional units from cloud cover (okta[17]).

Summary:

With this information, we can determine the data file types that we would receive and the varying units they are in. This is in preparation should there be a need to calculate conversion of units or convert various file types. This consideration is taking into account data that is collected from the various disciplines may or may not have the same idea of representation or significance even if they are in the same units. Conceivably, in knowing in advance what these information are and mean, we can look into unifying colour ramps that represent the same context or characterise data that are different. This adds to clearer visualisation and easier comprehension even when multiple data sets are displayed.

Question 10: "We found …"

Participants' feedback:

- Ways to enhance OTC through solar irradiance, wind and window location in a space after running simulations.
- Power plants generate more heat than buildings and transportation.
- We have developed models which quantify UHI occurrence and able to show its variants in spatio-temporal nature.
- Established that the two simulation tools 'ENVI-met[18]' and 'Ansys-fluent[19]' are adequately reliable for analysing comparative results.

---

14 Stl files is the file format for the abbreviation of SLA or SL. Stereolithography (SLA or SL; also known as stereolithography apparatus, optical fabrication, photo-solidification, or resin printing) is a form of 3D printing technology used for creating models, prototypes, patterns, and production parts in a layer by layer fashion using photochemical processes by which light causes chemical monomers and oligomers to cross-link together to form polymers.

15 Cxf File is created by Picasa, a free image editor and image sharing program developed by Google; created alongside the .JPG image when the user saves a collage; stores paths to the images that were used to create the collage, as well as the positions of the images in the collage.

16 A file with the XLSX file extension is a Microsoft Excel Open XML Format Spreadsheet file. It's a ZIP-compressed, XML-based spreadsheet file created by Microsoft Excel version 2007 and later. Spreadsheet files made in earlier versions of Excel are saved in the XLS format. Excel files that support macros are XLSM files.

17 In meteorology, an okta is a unit of measurement used to describe the amount of cloud cover at any given location such as a weather station. Sky conditions are estimated in terms of how many eighths of the sky are covered in cloud, ranging from 0 oktas (completely clear sky) through to 8 oktas (completely overcast). In addition, in the SYNOP code there is an extra cloud cover indicator '9' indicating that the sky is totally obscured (i.e. hidden from view), usually due to dense fog or heavy snow. When used in weather charts, okta measurements are shown by means of graphic symbols (rather than numerals) contained within weather circles, to which are attached further symbols indicating other measured data such as wind speed and wind direction.

18 ENVI-met software allows you to create sustainable living conditions in a constantly changing environment. With ENVI-met's interactive tools you can dive into any aspect of the microclimate complex and analyse how your designs perform. ENVI-met is the most evaluated microclimate model available, proving its capabilities to accurately simulate the outdoor microclimate for any place on the Earth.

19 Ansys-fluent is the industry-leading fluid simulation software used to predict fluid flow, heat and mass transfer, chemical reactions and other related phenomena. Known for delivering the most accurate solutions in the industry without compromise, Fluent's advanced physics modeling capabilities include cutting-edge turbulence models, multiphase flows, heat transfer, combustion, shape optimization, Multiphysics etc.

- Heat release at the rooftop or higher levels minimizes the impact on thermal comfort at pedestrian level. Inside the street canyon both air temperature and wind speed patterns can be modified due to AH release.
- Established the surface temperature of Singapore based on measured data gathered from satellite and academia databases.
- Identified suitable statistics to model how power plants in Singapore are dispatched.
- Found that electrification of transport would produce a six-fold reduction of energy use on the roads. A three-fold reduction of energy usage overall since some energy will be used for the generation of electricity for the electric vehicles.
- Autonomous vehicles will produce a six-fold decrease of heat production while also reducing the overall travel time of the commuting population.
- Found that the baseline and current level of UHI for Singapore based on a modelling basis. Results were validated from measurements of NEA Meteorological Service Singapore (MSS).
- OTC semi-outdoor space namely, Asia Square, one of the study areas selected, performs well and the measurements and modelling techniques done provides this same output.
- Urban design and assessment of the impact of UHI and OTC can be utilised as used cases and the execution of these simulations can be done independently by the researchers themselves.
- We found that Singaporeans are willing to sacrifice on average 0.43% of their annual income to mitigate UHI. The level of willingness-to pay (WTP) increases with income but decreases with age. Students, men and people with children are willing to pay more. Additional analyses with behavioural attitudes and lifestyles suggest that the level of UHI awareness, positive attitudes towards UHI mitigation strategies as well as preferences for outdoor activities are positively correlated to the willingness to pay.
- We found that there are 17 local climate zone clusters of which are used as a baseline and different weather types by other researches. We would be building upon these findings for further analysis in combination with other parameters.
- We have attained resultant values that are spatial, temporal and hourly of PET, air temperature, wind speed, relative humidity and solar radiation. These results corresponds the performance of various strategies to the different representative weather types.
- We have found that building energy and anthropogenic heat is mainly related to building morphology (volume, height and density) and occupancy types (residential, office).

- Local climate zone classifications often focuses on the morphology but when it comes to occupancy type aspect, the high variability of its nature is often neglected assumptions and parametrizations.

Summary:

With the findings gathered, we can get a better understanding of the current status of the different studies and its potential growth when the study continues. In thinking forward, the interface can explore into developing more tools to support user(s) continued efforts. Such an expansion would require flexibility for user(s) to interchange offered tools from an inventory or perhaps create new analysis tools to meet those specific study needs.

Question 11: "This is important because..."

Participants' feedback:

- We found value in the visualisation of the different designs under environmental factors. This is so that we can plan and design better buildings before the actual build.
- We need to better understand the influence of environmental conditions and its effects on everyday living spaces.
- So that planners and policy makers can make informed decisions within the constraints of parameters and limitations of resource.
- We need understand how heat is dispersed in urban areas and help develop the right design scenarios.
- In doing so would provide a more holistic definition of the UHI situation, validate the model used and create planning infrastructure guidelines.
- This would help in downscaling the power plant heat. Establishing the fundamental data of how power plants dispatch heat and compare it to available statistics.
- Provide insight to future scenarios and their implications to help policy makers create regulations and execute policies that effectively reduce anthropogenic heat, improve OTC, hence a better quality of life for all.
- Improve modelling capabilities in assessing strategies utilised, we can improve OTC. Which also helps in understanding and analysing the country's UHI as a whole.
- The automation and simplification of running simulations makes research work more efficient and productive. Thus, create more opportunities invested in actual research.
- These findings help decision makers, planners, researchers alike compare a large variety of strategies and make a more informed decision when planning or building a district.
- It helps to build a design guideline that would be useful for future planning as it would facilitate better understanding of the areas with similar microclimatic conditions.

- Data about energy consumption are crucial in understanding the impact of anthropocentric heat by buildings.
- It helps in correctly categorising the spatio-temporal impact of buildings' anthropogenic heat (e.g., air-conditioning usage) and have a fuller understanding of the building component with all the factors that contribute to its anthropogenic heat.

Summary:

From the feedback we can understand what is important and why it is in the different user's frame of mind. It also underlines how the different studies contribute or connect to each other. Similarly, we can also see how far along the user(s) are into their respective investigations. This is would also provide a window of opportunity to do some explorative research into the different ways of illustrating their findings.

Question 12: "This would be presented as..."

Participants' feedback:

- Powerpoint slides to the design team.
- Scientific findings to the advisory board, to gather further input and an eventual technical report.
- Visualisation tool that provides technical presentations.
- Urban design guidelines (planning and mitigation strategies).
- Spatio-temporal heat map comparisons.
- Digital platform that completes a cycle of input and output. Namely input parameters, run simulations and results for analysis.
- Technical report and an input to an urban design guideline.
- Graphs, tables, charts that explain the aggregated results. For full analysis as an entire city distribution, a stacked bar of energy consumption in gridded cells uniformly distributed would be the most straight forward depiction. More detailed information can also be provided at the building level for microscale case studies.

Summary:

From the mentioned types of deliverables, we can determine what kind of files should be provided on the platform as the final output. Being a system that is predominantly visual in its analysis, these three-dimensional visualisations, diagrams, analysis and recommendations would also need to be exportable in that manner. Not only as an image but also in a commonly recognised file format as well.

Question 13: *"Kindly add any comments or aspirations that you may have for the Decision Support System development."*

Participants' feedback:

- Be able to compare two or more urban design scenarios at a time.
- Allow dynamic on-the-fly (real-time) edits on existing scenarios or create 'new' scenario permutations from pre-existing scenarios.
- Export the DSS findings/scenarios as GIS layers (so that users can overlay their own data on top of DSS analysed GIS layer as deliverables).
- To have other key indicators of urban design like capital and operational expenditures aside to outdoor thermal comfort and urban heat island factors.
- Boxplots that can show the relationship between anthropogenic heat of buildings, transport and powerplants over several days.
- A decision support system that is visually strong and easily understood by all types of users. Perhaps flexibility in catering to different comprehension levels of the platform usage (e.g., basic usage to advanced analysis panels).
- A platform that can run on any type of computer (e.g., PC, Mac).
- Ability to allow users scripting/programming of their own features or input patches to conduct specific analyses required.
- Profile of the users of the platform and their usage of the platform. To discover the variations of the type of analysis that can be done and in turn the capabilities of the platform.
- Dynamic three-dimensional visualisation with ability to change and see the new chosen parameters instantly (real-time edits).
- Customisable needs (interface panels), interactivity (allows visualisation interaction/ dynamic changing of parameters), derive at a recommended decision and easy to learn.
- To incorporate saved energy consumption be translated into monetary figures.

Summary:

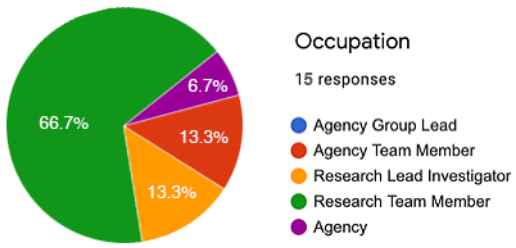
Based on this list, we can identify what are the user(s) needs and desires. Some of which are also interesting ideas to explore in the DSS platform.

4.3 Usability Test[20] Analysis

To begin, user(s) were not briefed prior on the tasks or what the interface would contain. After user impressions are collected, the user(s) are then introduced to the functions of the system. The following are three parts to the usability test. Part one is familiarization, part two is the actual usability tasks and part three is an open study of the user's preference and needs.

In part one familiarization section, questions are posed to the users with its corresponding intent write up after each question. Some answers gathered are in statistical percentages whilst some only require user(s) feedback. Participants' feedbacks are comments and observations from or of the users should there be any. The summary write ups are inferred assumptions, opportunities and potential areas of exploration based on the answered statistics/ feedbacks.

Each question is analysed collectively on how users found the difficulty level in executing prescribed tasks. The easier the task, the lower the score (e.g. 1/5) and the opposite (e.g. 5/5) being the hardest. Therefore, the benchmark for an acceptable pass is **(2/5) and below** from each user. The **total resultant score** has to be **≥ *40%***. Total participants: 15. (3 Agencies I 2 Senior Researchers I 10 Team Researchers)



0%	Agency Group Lead (0)
13.3%	Agency Team Member (2)
13.3%	Research Lead Investigator (2)
66.7%	Research Team Member (10)
6.7%	Others – labelled as "Agency" (1)

Part One: Familiarization Section

Question 5: *Does the interface provide an impression of its purpose?*

Intent: To verify if what is presented on the interface, is apparent to the user. Should it be deemed so, what does the user think are the next steps to move forward. Should it be deem not apparent, what does the user perceive they are reviewing. Observe how the user(s) decipher how it is used and how they feel it should be used.

20 Usability Test - Blank survey can be found at the end of this document in glossary.

Statistic:

No.	Question	Voted Outcomes
5	Does the interface provide an impression of its purpose? **Result: Needs improvement**	Agencies (7) Senior Researchers (6) Team Researchers (23) **Total: (36) 48%**

Participants' feedback:

- It is able to compare two or more urban design scenarios.
- User commented that there should include a north-sign (to help user distinguish direction and orientation of the sun).
- The buildings look blurry and there is no clear definition between one building from another.
- User mentioned that interface looks busy and had no clear indication of usage order.
- User said there was no context of what was being looked at and perhaps it would be helpful to have a description of the various components on the interface.
- User said three-dimensional space visual looks blurry and could not tell what was seen are buildings at first glance.
- User suggested to have better visualisation for roads. User guessed what looked like 'buildings' was also blurry. User could understand that what was seen is a study area but felt that there was no context of what is being looked at within the said area and that made it difficult to derive a proper impression.

Summary:

Overall, the interface is not apparent on what it is displaying. The three-dimensional visuals though are in a prototype stage, was not sufficiently clear on what is being shown to the users. The various visual elements within the study area needs to contain more information or visual details for it to be evident. Perhaps a mouse over on titles for explanation of component tools. User(s) who can identify the visuals, had difficulties in moving forward to its usage as the interface did not lead into the purpose of its tools and how their used. This gives us indication that an overview or an introduction of the study context should be shared with user prior to usage.

Question 6: *Does the interface provide clarity of its components?*

Intent: To verify if users found the interface components self-explanatory. If the tools match the usage of user(s) common conventions. If not, which ones did not meet that expectation.

Statistic:

No.	Question	Voted Outcomes
6	Does the interface provide clarity of its components? **Result: Needs improvement**	Agencies (9) Senior Researchers (6) Team Researchers (25) **Total: (40) 53.33%**

Participants' feedback:

- User asked what is an exposure map, what is the difference between weighted and an unweighted exposure.
- User asked for an explanation of what the binary function and exposure map does.
- User asked by what method was the weighted effort done in and by how much.
- User felt that exposure map was not clear and asked if numbers in the legend were related to the exposure map. User clicked on it, then realises that it correlates by highlighting on the legend the area of interest.

Summary:

There were varying queries and observed guesses aloud by the users when user(s) were deciphering the interface components. Users were interested in understanding them and asked in detail how these components worked. In some instances, users made accurate deductions or clicked about to find out the tool's purpose. Others were interested in where the data originates, how it is used and contributes to the user's needs. This is a substantial area of interest, it is therefore necessary to have helpful cues and information near these components to explain or illustrate its usage to the user.

Question 7: *Does the interface appear to have a sequential order?*

Intent: This is to discover if the interface is intuitive in leading the user into the functions of the system. To verify if the interface tools meet the conventions of common user(s) practice.

Statistic:

No.	Question	Voted Outcomes
7	Does the interface appear to have a sequential order? **Result: Needs improvement**	Agencies (11) Senior Researchers (10) Team Researchers (37) **Total: (58) 77.33%**

Participants' feedback:

- There is no segregation between the different tool components. There should also be explanations of what these tools do. How they are related and where are they from (this reinforces the notion of cues for the tools).
- User felt that there was little to no order as to how to use the interface.
- User commented perhaps numbering the components to tell sequence or a step by step title bar that appears after a task is done.
- User could guess the order roughly based on looking from left to right (*user instincts),* however user(s) were unsure when it came to the panels on the right (This refers to the analysis and recommendation panels).
- User mentioned hinted steps to the components to suggest activity required to move forward in usage. Component panels in full colour whilst analysis and recommended panels could be dark and not clickable to show inactivity.

Summary:

User(s) general concerns was there was no clear division between an input field to another. Especially so on the analysis and recommendation panels. Some users suggested a step by step aide in the usage or lit/unlit panel hints in the components to explain activity required to move forward. This could be useful to new users to encourage exploration or suggest effort to carry out a task without putting down instructions down explicitly. It is clear that this aspect of the interface needs to improvement.

Question 8: *Any thoughts/ suggestions on how it should appear?*

Intent: To ascertain clarity of content and if placement was apparent.

Statistic:

No.	Question	Voted Outcomes
8	Any thoughts/ suggestions on how it should appear?	N.A

Participants' feedback:

- There is no clear segregation between user input required panels and the analysis panels. User was unsure what can be interactively adjusted and in what order to start.
- There is no clear sequential order as a whole.
- User is used to a 'one menu' task bar with step by step how-to. User's suggestion of a 'one menu' bar here refers to a global navigation bar (e.g., the conventional 'home' icon that shows all its contents), this menu then splits the interface into different parts for different tools.

- Scenario selection does not have a title heading called 'scenarios', similar observation on the weather type selection as well.
- Drawer on scenario selection does not close back, it needs to be clicked on again to close (this closing mechanism should be auto after selection is made).
- User mentioned that there should be a tutorial or walk-through or a landing page to explain/orientate/introduce the user as to what the components are for, what the other panels do, what are the objectives or simply how to start.
- User commented that there should be clear distinction between parameter inputs, the analysis and the recommendations.
- User suggested to value add usage by allowing customisation of panels. To allow users control over the panels and set their own pre-set panels whenever they use it as long term convenience.
- User suggested to show more details of the colour scale (the breakdown) and also the definitions of the different components.
- User suggested that the exposure map should match colours on 3D space visualisation and the scenario (mitigation strategy) chosen should match the 3D space aesthetically.
- Another user suggested segregation or divide the different panels by means of space or with colours. A colour for the cluster of input selections and another for the cluster of analysis panels.
- User said it was important to have description of the different components. To explain how the components work and what it does.
- User suggested arrow indicators on interface to help aide the user on how to use the tools.

Summary:

Users require step by step instructions or hints as to how to use the interface. This could be facilitated with a workshop introduction or a quick tutorial walk-through during the first launch of application. Other alternative methods of guiding the user throughout the interface should also be explored whilst using the tool to ensure if earlier coaching efforts are ignored. Further aids within the interface could also come in as an integrated 'help' chatbot, frequently asked questions link or icons that contain information that users can read to understand the respective tool functions. Clearer division between panels is needed. We can explore division of panels based on input required panels and other non-interactive components.

Question 9: *What is your opinion of the interface? (Aesthetics)*

Intent: To gather the general preference of the users on the interface aesthetics.

Statistic:

No.	Question	Voted Outcomes
9	What is your opinion of the interface? (Aesthetics)	N.A

Participants' feedback:

- Aesthetically it is acceptable. Perhaps suggest a menu bar like windows (some kind of global navigation concept to start user off).
- User felt that the interface is aesthetically acceptable. However, we could also try themes of a different colour (white/ custom). Different modes for interface and three-dimensional space, white modes appears more approachable to the user.
- User commented that the interface looks modern and dark mode works well to bring up the three-dimensional visual or representations. Could explore the title bars to be less stiff looking.
- User suggested to reduce the amount of tools on the interface so that it to look less cluttered. More minimalistic stylistically.

Summary:

The general consensus is the interface is aesthetically acceptable. We could however explore a light colour mode from its current one or a mode that addresses user(s) who may have colour vision deficiencies. To attempt a less rigid presentation, we can look into introducing more organic shapes or minute edits to stylistic forms (e.g., rounding off straight edges of shapes).

From this point onwards (Question 10), the user(s) are shown how to manoeuvre themselves in the three-dimensional space with their keyboard and mouse. User(s) are introduced to the different panels, their purposes. What 'scores' accorded in the recommendation panels are and how they are calculated.

Question 10: *How do you feel about the movement latency? (Speed of movement)*

Intent: To identify movement issues (computational lags), understand user(s) comfort level (motion sickness) and gather user(s) common conventions and habits.

Statistic:

No.	Question	Voted Outcomes
10	How do you feel about the movement latency? (Speed of movement) **Result: Success**	Agencies (3) Senior Researchers (3) Team Researchers (15) **Total: (21) 28%**

Participants' feedback:

- User commented on being accustomed to holding down scroller wheel for panning, using the wheel to zoom and the left mouse for moving around (e.g., other softwares like rhino[21], sketchup[22], autocad[23]).
- Movement of the keyboard left and right keys (WSAD) are a little too great compared to the up and down buttons which are more incremental. The preferred movement is that the up and down keys.
- User felt that it was not moving the way it was expected. User was moving left/right/up and down and was expecting it to move at the current elevation's 'view' of left/right/up and down, instead the movement went literally into the study visual space. User suggested that perhaps another button or shortcut tool for the differentiation in movement.
- User suggested to modulate zoom capabilities. Speed scroll to zoom more and slow scroll for increments.
- The (WSAD) keys should be for current perspective view movements and for the mouse movement to make immersive movements into the three-dimensional space *(reoccurring comment)*.

Summary:

User(s) feedback on the movement of the viewing perspective and the movement of the immersion into the three-dimensional space should be separated. This two movement types should also accommodate its movements in increments and fast zooms. This could be explored as mouse scroller for immersive movements into three-dimensional study space and keyboard (WSAD) keys for user(s) of view-points (this could also be done vice-versa).

---

21 Rhinoceros (typically abbreviated Rhino, or Rhino3D) is a commercial 3D computer graphics and computer-aided design (CAD) application software developed by Robert McNeel & Associates, an American, privately held, employee-owned company founded in 1980. Rhinoceros geometry is based on the NURBS mathematical model, which focuses on producing mathematically precise representation of curves and freeform surfaces in computer graphics (as opposed to polygon mesh-based applications).

22 SketchUp is a 3D modeling computer program for a wide range of drawing applications such as architectural, interior design, landscape architecture, civil and mechanical engineering, film and video game design.

23 AutoCAD is a commercial computer-aided design (CAD) and drafting software application. Developed and marketed by Autodesk,[1] AutoCAD was first released in December 1982 as a desktop app running on microcomputers with internal graphics controllers.

Question 11: *How do you feel about the movement dexterity? (Manoeuvring smoothness)*

Intent: To identify movement issues (computational lags), understand user(s) comfort level (motion sickness) and gather user(s) common conventions and habits.

Statistic:

No.	Question	Voted Outcomes
11	How do you feel about the movement dexterity? (Manoeuvring smoothness) **Result: Success**	Agencies (3) Senior Researchers (3) Team Researchers (15) **Total: (21) 28%**

Participants' feedback:

- User commented that the manoeuvring in three-dimensional (3D) space needs some getting-use to but it should not be too difficult to catch on.
- Perhaps to have a 'hand tool' to move on the surface of the 3D space, cause the current up/down & left/right movement brings viewer into the 3D space *(reoccurring comment).*
- User finds the pivoting aspect may not be necessary and for panning, the user is used to holding down the mouse scroller to do it.
- User felt that the pivot motion was strange as they would move it by panning and not tilting the diagram altogether (user is used to using rhino software movement).
- User does not like the pivoting mechanism. Feels that the pivoting movement is pivoting the subject and not the view of the subject.

Summary:

Most user(s) found the pivoting action redundant and we may not need it in the system. It is observed that the movements in navigating the 3D space did not require that movement. Having movements from the current point of view without moving into the 3D space as a comment has been brought up again in this query, reinforcing the notion to be important.

Question 12: *How do you feel about the overall negotiation of 3D space?*

Intent: To identify movement issues (computational lags), understand user(s) comfort level (motion sickness) and gather user(s) common conventions and habits.

Statistic:

No.	Question	Voted Outcomes
12	How do you feel about the overall negotiation of 3D space? **Result: Success**	Agencies (7) Senior Researchers (3) Team Researchers (19) **Total: (29) 38.67%**

Participants' feedback:

- User suggested a 'reset button' to restart the view of the study especially after exploring. Perhaps a 'step' backward like undo as well.
- User mentioned that the centre of the image was not the model but an off corner part of the model.
- Should both 3D visualisation rotate, it should rotate from the centre axis of the model. It looks to be to be off.
- User was open to 3rd person view point to control spectatorship of study model. User mentioned preference to this as user felt more in control of how it appears overall and feels less dizzy due to the immersive navigation.
- User does not like the pivoting mechanism. The pivoting is felt to be of the study area and not the view point *(reoccurring comment).*

Summary:

A 'reset' view would be helpful to re-orientate the user to the beginning should they require it. An 'undo' view aspect might be difficult to achieve as there are too many potential viewpoints the user could be in but that might be something worth pondering upon. To control the study area as a 3rd person view might be another avenue we may explore. To let user have an overview and command over what they are looking at. Similar to an external controller over how the 'scene' is seen while analysing.

Question 13: *Any thoughts/ suggestions on how it should be?*

Intent: To gather consensus of the user(s) on the overall navigation and usage of the interface.

Statistic:

No.	Question	Voted Outcomes
13	Any thoughts/ suggestions on how it should be?	N.A

Participants' feedback:

- The user understands that the test is a prototype and the study area has its view perspective locked so that the user does not go "under" the study area, however the user has mentioned a keen interest in looking at the study area on a street level. To be walking amidst the 3D space and 'physically' see the effects, to profile the whole terrain (user finds it more immersive).
- User commented that the buildings looked blurry. As in there is no clear definition of where the buildings ends and another starts. It was suggested that the buildings be more opaque from a distance and visualised in its skeletal form upon closer inspection. This is to see the cross section of the building, like its pillars, windows, different levels and lift shafts (this was favoured by multiple users).
- Perhaps a button or shortcut key to fit full-screen visualisation based on current perspective (ability to hide all the interface panels).
- User commented that they are used to google earth manoeuvring abilities.
- User suggested better visualisation of trees.
- User mentioned that having cross-sectional views of the study area would value add analysis as it helps understanding sun orientation, soil and wind direction.
- User felt exposure map was unclear. Legend did not correspond to the 3D space visualisation. If a selection of the study area is made, the other parts of the study area should be another dull colour (e.g., All unselected section should be the same shade of grey).

Summary:

The general consensus is that the visualisation needs to improve. To be able to see surrounding areas and exterior attributes of the buildings clearly. To also be able to see the building skeletal fabrication upon closer review. Three-dimensional visuals to have directional cues to illustrate sun and shaded areas. Potentially, have hiding abilities of the all interface tools to allow maximum preview of the analysed study area.

Question 14: *Does the visual depiction provide a context of what you are reviewing?*

Intent: To establish after the explanation of usage and the components if it is now clearer. Should if not be, how do they feel about it.

Statistic:

No.	Question	Voted Outcomes
14	Does the visual depiction provide a context of what you are reviewing? **Result: Success**	Agencies (7) Senior Researchers (3) Team Researchers (13) **Total: (23) 30.67%**

Participants' feedback:

- User commented that perhaps more information is required to understand the different panels fully as to what they do, where they are from and how they are connected to each other.
- It is observed that user clicked on 3D image to change scenario.
- It is not apparent to user as to how the ranking score is understood on the panel. From high to low and what scenario verses another. Perhaps allow user(s) to decide ranking order.
- User suggested ability to change viewing spots of the study area at a click.
- User mentioned that perhaps consider putting a north sign (in the exposure map panel since the image is corresponding to the 3D space view).
- It is observed that more users use the (WSAD) keys to move about than the arrows on the keyboard.

Summary:

It is interesting to observe that more user(s) utilise the (WSAD) keys over the arrow keys to manoeuvre around the study space. Almost all user(s) require more extensive explanations to each tool that is being shown even after explanations. This however could potentially be too text heavy for an interface. Separate allocation of space may be required for these information.

Question 15: *To begin analysis, you would first need to pick your primary selections. Which terminology are you more likely to identify with of this notion?*

Intent: Discover what various user(s) deem as a common terminology for primary input.

Statistic:

No.	Question
15	To begin analysis, you would first need to pick your primary selections. Which terminology are you more likely to identify with of this notion? **Voted Outcomes** **Agencies | Senior researchers | Team researchers** *Components:* **(0)** *Input:* **(12)** *Parameters:* **((11)** *Criterion:* **(1)** *Other:* Variables **(4)** Constants **(1)** Configuration **(1)** Indicators **(1)** **Result: Parameters (Most commonly used terminology)**

Participants' feedback:

- Agencies | Highest two terminology: **Parameters** and Variables
- Senior researchers | Highest two terminology: Input and **Parameters**
- Team researchers | Highest two terminology: Input and **Parameters**

Summary:

It is established that most users deem "Parameters" as a common terminology they identify with to begin setting up an analysis study.

Question 16: *What do you understand from the phrase 'weather type'?*

Intent: To investigate if information presented is apparent to user(s) and discover user(s) interpretation of information.

Statistic:

No.	Question	Voted Outcomes
16	What do you understand from the phrase 'weather type'?	N.A

Participants' feedback:

- A description or depiction of a season or weather type.
- A classification method of climate related variables into sets of small clusters.
- Representative of a weather, an average weather condition over a specific season, a seasonal effect or a cluster of weather occurrences (a meteorological condition).
- User said that it is an assembly of weather values of it wind speed, humidity etc. over a period of time.

Summary:

Generally, user(s) have a grasp of the term 'weather type' and its meaning is apparent.

Question 17: *Do you work primarily with weather types specified independently or seasons stipulated by Meteorological Service Singapore (MSS)?*

Intent: To discover user(s) weather type resource and if there are other aspects of interest.

Statistic:

No.	Question	Voted Outcomes
17	Do you work primarily with weather types specified independently or seasons stipulated by Meteorological Service Singapore (MSS)?	N.A

Participants' feedback:

- User mentioned that their entire team uses MSS. With one user commenting if off the four seasons in MSS, there are inter-monsoons that are similar, the similar monsoon can be collapsed into one (suggestion for next iteration categories for weather type).
- User commented that the team uses MSS. However, user further added feedback that although the country has generally stable seasons, there are scenarios whereby it is raining in 'Jurong' (located far west of Singapore) and it is not raining in 'Pasir Ris' (located far east of Singapore). It would be beneficial if weather conditions worked on in DSS could be even more accurate to reflect actual weather at location.
- User(s) mentioned that there are also other conditions that they are currently looking into, like 'wind driven rain'. User mentioned that the team is invested in venturing more in this direction as well.
- User works with MSS and is interested in the impact of this on pedestrian sheltered walkways or foyers etc.
- User uses weather types that are from both MSS and from their own independently specified weather types.
- User uses GDAS (Global Data Assimilation System).
- User mentioned that they utilise predefined weather types established independently.
- User uses MSS and consider the weather at its coolest and warmest only (temperature consideration only).
- User does not work with weather types.

Summary:

Generally, the user(s) utilise the MSS as their preferred weather resource. There is feedback for more accurate reflection of weather conditions on locations instead of the general read of the weather as a country. It is interesting to find that user(s) are also invested in examining 'wind driven rain' as one of the weather type considerations. Singapore, being a tropical country is also predominately reigned by rain throughout most of the year. This weather condition could potentially be an important impact to everyday lives, property and OTC.

Question 18: *What do you understand from the phrase 'exposure map'?*

Intent: To investigate if information presented is apparent to user(s) and discover user(s) interpretation of information.

Statistic:

No.	Question	Voted Outcomes
18	What do you understand from the phrase 'exposure map'?	N.A

Participants' feedback:

- User(s) mentioned that it is the seen as the area that people are exposed to (this could mean sunlight, heat or the weather in general).
- Some users have described this to represent the spatial importance of different locations in accordance to the different criteria of the user (e.g., social aspects).
- User(s) commented that it is how exposed you are in a space, different areas of vulnerability.
- User(s) replied that it was how sensitive a location is or how much exposure is the subject is to the heat, sunlight, its relative humidity (user said that this could possibly link backs to climatic variables).
- User replied that it was the risk multiplied by damage. It is how likely people are to experience a negative/bad event on a map.
- The general feedback from user(s) are that the colour impression of red is warmth and blue for cooler temperatures (in reference to the colour ramp).

Summary:

Users all had slight variations in the interpretation of the phrase. Generally it is seen as the amount of sunlight, heat or importance of a specific area. The user(s) all had the overall impression of the colour blue depicting cooler temperatures and the colour red to depict warmer temperatures.

Question 19: *There are three different exposure areas on the interface: street, sidewalk, plaza/park. In the planning and design of districts, are there also other exposure areas considered?*

Intent: To investigate if user(s) had other exposure areas in their considerations and potentially discover other areas of interest.

Statistic:

No.	Question	Voted Outcomes
19	There are three different exposure areas on the interface: street, sidewalk, plaza/park. In the planning and design of districts, are there also other exposure areas considered?	N.A

Participants' feedback:

- User mentioned elevated plazas, air-con vents, transport nodes, POPs (privately own public spaces).
- User replied playgrounds, communal spaces, gardens, precinct parks, outdoor/recreational spaces.
- User commented rooftops, covered linkways and development walkways.
- User(s) mentioned that it is any location where people would be most of the time. This should include places like terraces, plazas, sidewalks, crossings.
- User(s) mentioned communal spaces that people congregate (e.g., outdoor, semi-outdoor, indoor areas, elevated podiums, rooftops, facades).
- It is observed that user was clicking on the exposure map to test if anything happened instead of the numbers next to it (exposure map panel on interface).
- User(s) mentioned pedestrian crossings, bridges, parking spaces, intersections of human traffic, terraces on high floors of buildings and facades.
- User(s) replied other areas like schools, hospitals, hawker centres, playgrounds and parks. Active communal spaces where people gather or more vulnerable people may be found. Perhaps even more emphasis should be placed on these locations as the potentially vulnerable populace converge in these areas.

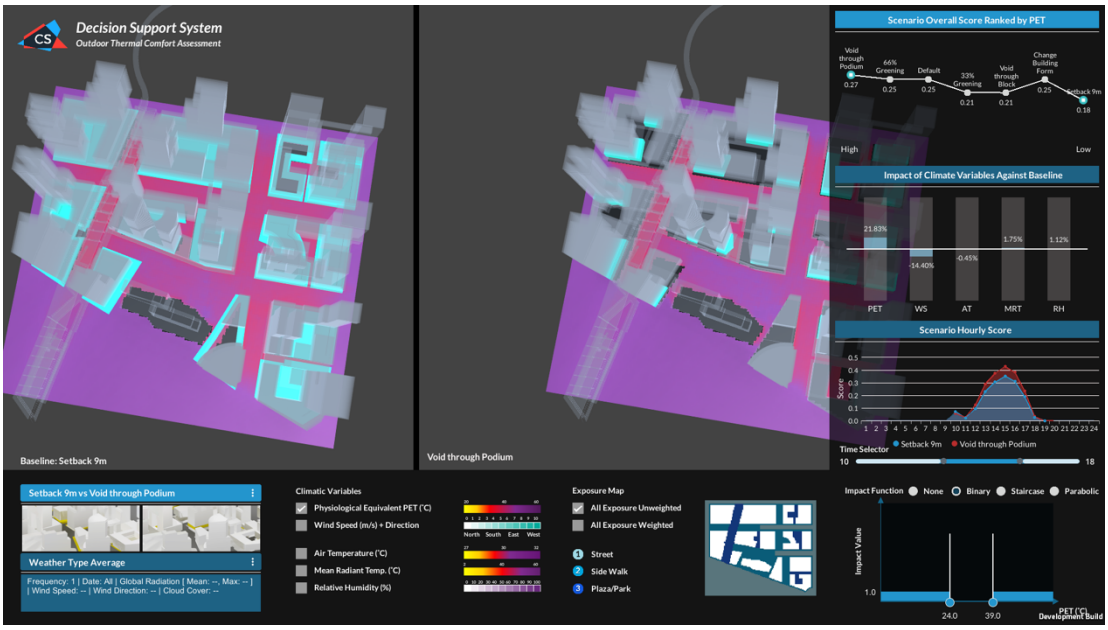
Summary:

Users of different users have shown interest in different areas depending on their scope of focus. Generally, the exposure areas allocated in the study met the expectations of the all users. An interesting was place more weight on areas that host the vulnerable populace or highly active communal spaces. Potentially more care may be needed in consideration to the infrastructure or architectural builds surrounding these locations as they accommodate the senior or special needs citizens. The young or vulnerable near or at schools and hospitals. Another interesting consideration in terms of exposure area is the façade of buildings.

The focus of the usability tasks is on where it can be improved, why are some of the user interface (UI) unable to meet the expectation of the users and how we can improve it. The successful and unsuccessful rate of answers are indicative of which aspect of the platform needs work. Margins of error/ incorrect answers from all the users were generally slight. Under some circumstances, whereby incorrect answers were accorded are mostly due to user's enthusiasm (user felt that the parameters 'they' set on the interface were close enough to the prescribed parameters) to move on to the next question or motivation to pursue accuracy was lost as the UI was not helpful/ easy to utilize.

In part two usability test section, questions are posed to the users with its corresponding statistical percentage outcome. Some of these questions only require user(s) feedback. These feedbacks are comments and observations from or of the users should there be any. The summary write ups are inferred assumptions, opportunities and potential areas of exploration based on the answered statistics/feedbacks. Each question in the usability test are answered either correctly or incorrectly. The more the number of correct answers given, the higher the success rate. Therefore, the benchmark for each of question has to be **≤60%** out of the total respondents to be **successful**, whereas scores **≥60%** implies a **need** for **improvement**. (Diagram) is a screenshot of the prototype interface tested on users.

Diagram 2



Part Two: Usability Task Section

Question 20: *What is the overall PET score for the scenario 'Setback 9m'?*

Statistic:

No.	Question	Scored Correct
20	What is the overall PET score for the scenario 'Setback 9m'? **Result: Success**	Agencies (2/3) Senior Researchers (2/2) Team Researchers (7/10) **Total: (11/15) 73.33%**

Participants' feedback:

- It is observed that the user was unsure of where to start on the interface. They were looking for a title bar to hint how to start. User then started to work from left to right at the bottom of the interface.
- User(s) have suggested a type-in field for the impact function panel. This has been feedbacked by multiple user(s). Some user(s) commented that the dragging of the toggle takes too much time to accurately place it at prescribed parameters (this notion could also be applied to the timeline toggle).
- It is observed that the user was clicking on scores to see what it does. User also tried clicking on climatic variables (user thought in both cases that it was interactive).
- Although some users did not mention issue but some users took a while to figure out how to deselect a scenario after one was picked. User needed to go back to previously selected scenario to uncheck previous selection to select a new one. User looked disturbed by this.
- It is observed that user could not locate timeline and scenario listings easily without prompt.
- User asked if ranking was in ascending or descending order.
- User commented that ranking of scenarios through scores are not obvious.

Summary:

It is evident that there is difficulty in the act of changing scenarios. It is not sufficiently intuitive as user(s) needed to go back and forth to uncheck the boxes to deselect previously made selections. The change needs to be automated so that the scenarios swap themselves out when a new scenario is selected. This need to return to uncheck previously chosen selection is cumbersome and would definitely a cause of annoyance to user(s) in the long term. The timeline controller needs to be placed in a more apparent and clear allocated space. We need to relook at the naming of the score labels and also explore the possibility of having the score panel accord control over to the user(s) to rank in order of their choice (be it ascending or descending). We should also consider having enlarging abilities on all interface panels as this would make reviewing clearer for user(s).

Question 21: *(Setback 9m) At what time is the PET score at its highest at 0.971?*

Statistic:

No.	Question	Scored Correct
21	(Setback 9m) At what time is the PET score at its highest at 0.971? **Result: Success**	Agencies (3/3) Senior Researchers (2/2) Team Researchers (10/10) **Total: (15) 100%**

Participants' feedback:

- User suggested 'timeline selector' to be aligned parallelly to 'scenario hourly score' so correlation is more apparent.
- User(s) commented that the streets and buildings should be more defined and detailed to be identified more clearly *(reoccurring comment).*
- It is observed that user was clicking on diagram of exposure map instead of the numbers next to it. It was not apparent that the numbers next to the diagram was clickable.
- The user commented saying the colour differentiation on the exposure map was not obvious and were too similar even when they highlight sections of the study area.

Summary:

The score panel needs to have more clearly labelled. Colours on pre and post selected states of the exposure map have to be relooked.

Question 22: *Of the two scenarios chosen, which faired the best?*

Statistic:

No.	Question	Scored Correct
22	Of the two scenarios chosen, which faired the best? **Result: Success**	Agencies (3/3) Senior Researchers (2/2) Team Researchers (10/10) **Total: (15) 100%**

Participants' feedback:

- User briefly mentioned that the impact function toggle should have a type in area to input the acceptable temperature. The dragging toggle was difficult to control and inputting would be faster *(reoccurring comment).*
- User mentioned that the impact function threshold for 'O' and '1' did demarcate if '1' or '0' was the threshold that was being looked at. More has to be done to explain that '1' was the range the users have determined/chosen to be

acceptable and everything outside the '1' range was not. User also mentioned that perhaps it could be colour interpreted (green and a void for the area not looked at or something to that implication).

- User mentioned that the decision matrix could perhaps be more obvious. The score does show which scenario performs better based on the parameters set but it is not revealed in detail about 'what' and 'when' it specifically made it perform better (this could be solved by having the decision matrix itself as one of the analysis panels).
- User mentioned to value add the information by colour coding the performance of all the scenarios to make it quicker to deduce how which ones did better.
- Ranking of the scenarios should be based on the best performing to the worst performing one. The numbers on the scenarios is the performance on average but there is no indication of which one is ranked #1. They are placed on the diagram high and low based on their respective score on the axis they reside (this should be re-sorted from best to worse score by the system for easier understanding).
- Scenario comparisons although have labels at the bottom of the 3D space of which one is baseline to the comparison, it could be more obvious if there was a visual indicator of which scenario is the baseline (e.g., the baseline scenario is indicated in blue with all analysis with regards to this baseline would have corresponding blue indication. Similarly this same effort would be applied to the comparison in a different colour).
- It is observed that some users derived their answers for this task question based on the statistics panel, some were based on the score panel saying the lower the PET the better the performance (cooler), some users derived their conclusion based on the 3D visual, where less purple is seen overall in the study area. Majority of the users went to the recommendation score panel for answers on which performed best.

Summary:

We can explore adding a visual indicators on the impact function toggle to depict where in the area the user(s) have selected to examine. Again, there is a repeat on the need for an input field for the impact function and a clearer rank indication for the scenario performance scores in the recommendation panel. The recommendation panel should also have these scored scenarios already sorted from best to worse for user(s) to review. User(s) have commented that revealing only the final score churned out by the behind-the-scenes computation is not sufficient. The decision matrix where the scores stem from also need to be brought to the forefront for the user(s) to review and analyse as well.

Question 23: *At what time did both scenario PET reading peaked at its worst?*

Statistic:

No.	Question	Scored Correct
23	At what time did both scenario PET reading peaked at its worst? **Result: Success**	Agencies (3/3) Senior Researchers (2/2) Team Researchers (10/10) **Total: (15) 100%**

Participants' feedback:

- User commented that the 'impact of climate variable against baseline' was very useful. It's important to be able to determine in detail which aspect was the cause of it performing better.
- User understands the logic of the higher the worse then PET and it is the opposite for the wind speed. It would take a little getting used to but should not be a problem. Perhaps consider making it easier to understand this with some sort of visual indication.
- User mentioned that ranking should be arranged in an order (ascending or descending). Most user(s) commented that #1 is commonly known for being the best performing.

Summary:

In this feedback we can see the usefulness of this analysis panel, however we could further facilitate quicker understanding of the outcome of all the climate variables by visually determining which performs to the intended ideal. For an example, the higher the PET reading, meaning the warmer it is could be depicted in red as it is not ideal. The higher the wind speed, the cooler it is and this could be depicted in green as it is ideal. So despite both readings are high and in the same direction on the analysis panel, user(s) can tell in a glance the difference in performance.

Question 24: *Among all the scenarios, which scenario PET scored the worse?*

Statistic:

No.	Question	Scored Correct
24	Among all the scenarios, which scenario PET scored the worse? **Result: Success**	Agencies (3/3) Senior Researchers (2/2) Team Researchers (5/10) **Total: (10) 66.67%**

Participants' feedback:

- User said the 'impact of climate variable against baseline' panel needed a description as to what the acronym meant. It was not immediately apparent.
- User commented that aside from the label at the bottom of the screen that indicates that the visual shown is the baseline, there is no other obvious implication of that is the baseline *(reoccurring comment).*
- User mentioned that they are more used to having a light coloured radio button (to indicate highlighted choice) verses a coloured dark radio button (to indicate not selected choice).
- User indicated interest in seeing break down of score in relation to costs as well. As the decision taken for execution is often in consideration of not only the scientific performance but also the various costs incurred during a long/short time period.

Summary:

There's repeated feedback of the climatic variables analysis being useful but user(s) also needed more information on its origins, purpose and how it is used. User(s) commented that the 'radio button' is opposite from what user is accustomed to, where selected buttons are lighter in colour compared to non-selected. There is also interest in showing greater detail in how cost correlates to the science in OTC. There is interest in the costs incurred for strategies and its trajectory from short to long term time spans.

Question 25: *Please rank the following in accordance to your priorities.*

Statistic:

No.	Question	Most Voted Priority
25	Please rank the following in accordance to your priorities. *Outdoor thermal comfort (PET)* *Wind speed and direction* *Mean radiant temperature* *Air temperature* *Relative humidity* *Energy saving* *CO2 emissions* *People preference* *Investment, maintenance operational costs* *Other: Wind driven rain, reduce energy, water and carbon footprint, anthropogenic heat, evapotranspiration/ water run-off, solar radiation/ shade.*	 **#1** **#4, #5, #8** **#4, #7** **#2, #9** **#5, #8** **#4, #5** **#3, #7** **#4, #6, #7, #9** **#4, #6, #7, ,#8, #9** ***Agency Results: Top 3 priorities*** ***#1 -*** Outdoor thermal comfort ***#2 -*** Costs ***#3 -*** People preference **Overall Results: Top 3 priorities** **#1 -** Outdoor thermal comfort **#2 -** Air temperature **#3 -** CO_2 emissions

Participants' feedback:

- Other factors user(s) consider are wind driven rain, reduction of energy, water and carbon footprint.
- Other factors by some user(s) are anthropogenic heat, evapotranspiration/water run-off, solar radiation/shade.

Summary:

As seen in the voted outcomes, outdoor thermal comfort is top priority followed by air temperature and carbon dioxide emissions respectively. There is also fair interest in various areas like 'wind driven rain', carbon footprint and solar radiation. These subjects could be research areas we could explore in future as they can also build an even more holistic understanding of the OTC and an informed infrastructural plan.

In part three open study section, each question is intended to be open ended. This is to encourage user(s) to share their needs, opinions and preferences. Feedbacks are comments and observations from the users, should they have any. Summary are write ups inferred from the feedbacks as assumptions, opportunities and potential areas of exploration.

Part Three: Open Study Section

Question 26: What are the areas of interest in your analysis?

Participants' feedback:

- User would like the ability to export the analysis as a geographic information system[24] (GIS) file. This is so that they may overlay it with their own GIS data and integrate it as part of their proposal presentation (e.g., the conditions analysed in the exposure map can be part of other planning efforts the user has).
- The user(s) are currently tasked to research and develop into the study of 'wind driven rain'. Following Singapore's government body, building and construction authority (BCA) guidelines, user(s) would like to see its effects and how it can be mitigated. User(s) mentioned for an example how wind or rain proofing might affect sunlight, if orientation would help. What would be the trade-offs and solar radiation effects on its surrounding.
- User would like to be immersed in the 3D space, to locate exact location of interest. Similar to walking about in the 3D space of the exposure map and witness where the heat source originates.
- User expressed an interest in solar radiation and shaded areas affected by weather in the scenario simulations.
- User mentioned solar radiation and rain avoidance on covered areas as an area of interest. To discover more information about pedestrian and transport traffic areas affected by this.
- User expressed interest in delving into social parameters of the vulnerable demographics (e.g., elderly or sick).
- User is interested in flooding, how energy generation translates into costs of electricity in the energy whole sale market.
- User is interested to see where heat source is generated, the surface temperature and the temperatures at different height levels.

24 A geographic information system (GIS) is a framework for gathering, managing, and analysing data. Rooted in the science of geography, GIS integrates many types of data. It analyses spatial location and organizes layers of information into visualizations using maps and 3D scenes.

Summary:

Multiple user(s) have feedback their desire to have the analysis be exportable into GIS format. This stems from the user's desire to build on or re-purpose the analysis studies done on OTC. User(s) would like to overlay their own information on these exported GIS files to build potentially other what-if scenario permutations. It would be held as a basis for other studies or craft design proposals. User(s) have also shown excitement in exploring OTC on various levels in the 3D space (e.g., pedestrian or at different heights of tall buildings). Seemingly akin to having an immersed experience of the studied environment and be spatially situated amongst the analysed data. Notable mentions by user(s) are interest areas like flooding, solar radiation, rain avoidance (associated to the field of 'wind driven rain'), energy generation to electrical cost relations, social parameters and its vulnerabilities.

Question 27: *How do you and the team conduct the analysis required for your interest areas?*

Participants' feedback:

- User mentioned that generally their architects would request for physical massing and the change/effects in urban form. User(s) would also research into shading, wind, building, floors and some other aspects on district and land parcel levels. What arises when interventions are applied to these buildings and the plans. User mentioned that teams are predominately interdependent.
- User mentioned they would run building simulations by using the Greenmark standards established by Engineering Systems and Design (ESD) and this would be used as the first cut of the master plan. Simulations are then detailed and the consultants would review and amendments would be made after. This process is iterative and their team works with guidance towards designing it successfully. Their final output would be a GIS overlaid presentation.
- User answered that they would run 3D simulations and carry out actual measurements commissioned for the research and compare results to see if there are any observations of shade as an hourly scenario. These findings are then presented to the upper management.
- User mentioned they would use georeferenced geometry of buildings and its location to calculate the sun and shade during the interferences throughout hourly changes.
- User(s) communicated that they work together with architects, climatologist, analysts and utilise their findings to build on further. Creating inputs to simulations and post process them into outputs of different permutations.

- User mentioned that they use 3D geometry from governmental bodies to develop hypothesis and scenarios. Which they later simulate with weather data, anthropogenic heat emissions to provide informed results.
- User(s) commented that they would carry out by setting parameters, running simulation models in different combinations then validated them after with actual measurements.

Summary:

We can understand from the feedback that most of the user(s) receive their directions from their respective department heads with guidance from consultants and conduct iterative efforts in running simulations. This is done with markers from standard guidelines as stipulated by the governing bodies or with actual measurements of actual site over time. These findings are then compared and then presented to upper management as a GIS visualization.

Question 28: What do you envision could be helpful in your analysis?

Participants' feedback:

- User(s) desire a platform that is universal in the sense whereby all government agencies use it as a common tool.
- User(s) mentioned that it would be most ideal if the scenarios within the platform are able to accommodate on-the-fly edits. Whether if it is pre-existing scenarios that the user can edit and re-simulate with conditions to get an analysis or create their own scenarios and await simulation reverts after a few hours. They find this to be very helpful.
- User would like to see marginal changes in analysis and likes the impact of climate analysis variable panel.
- User would appreciate if the exposure maps as GIS files and analysis could be exported as geo-reference layers, base-layers. This would be useful for planners and simulation users alike. So they can use it in partnership with their own data. Their presentations are generally presented as powerpoint[25] in google slides[26].

25 Microsoft PowerPoint is a presentation program,[7] created by Robert Gaskins and Dennis Austin[7] at a software company named Forethought, Inc.[7] It was released on April 20, 1987,[8] initially for Macintosh computers only.[7] Microsoft acquired PowerPoint for $14 million three months after it appeared.[9] This was Microsoft's first significant acquisition,[10] and Microsoft set up a new business unit for PowerPoint in Silicon Valley where Forethought had been located.[10] Microsoft PowerPoint is one of many programs run by the company Microsoft and can be identified by its trademark orange, and P initial on the logo. It offers users many ways to display information from simple presentations to complex multimedia presentations.

26 Google Slides is a presentation program included as part of a free, web-based software office suite offered by Google within its Google Drive service. The service also includes Google Docs and Google Sheets, a word processor and spreadsheet respectively. Google Slides is available as a web application, mobile app for Android, iOS, Windows, BlackBerry, and as a desktop application on Google's ChromeOS. The app is compatible with Microsoft PowerPoint file formats.

- User suggested to consider having the climatic variables shown one at a time. Perhaps as a dropdown bar would be more suitable than a checked box selection.
- User mentioned that it would be interesting if building scenarios can also accommodate building surfaces (material) and how it performs under different conditions *(reoccurring comment).*
- User commented to explore visual capabilities in switching from 3D to 2D. So it can be seen as a topological view. Reason being that sometimes 2D visualisation makes for better clarity in seeing analysis. To study cell by cell information and compare readings (e.g., hovering cursor over 2D visualisation).
- User mentioned that we could explore developing an algorithm that creates different designs solutions that could improve the overall performance of scenarios.
- User suggested less words/shorter labels on the panel titles *(reoccurring comment).*
- User suggested for custom loaded panels to be made available as an option for advance users who frequently use the platform *(reoccurring comment).*
- User suggested other exporting abilities like video, images in (.png[27]), (.jpg[28]), (.tif[29]) aside from a GIS layers.
- User would like the dashboard to have more cost curves against scientific analysis and more decision matrix supportive analysis *(reoccurring comment).*
- Would like to see more comparisons scenarios (more than two scenarios) at a time and have more analysis panels to see details across each performance.
- User would like to see demographic preference verses cost strategies and PET improvement. This is in effort to see how each affects the other.
- User suggested that it would be also good to see where the vulnerable population are located concurrently in context to where the solution strategies would be applied.

---

27 Portable Network Graphics (PNG), is a raster-graphics file format that supports lossless data compression. PNG was developed as an improved, non-patented replacement for Graphics Interchange Format (GIF).

28 JPEG is a commonly used method of lossy compression for digital images, particularly for those images produced by digital photography. The degree of compression can be adjusted, allowing a selectable tradeoff between storage size and image quality. JPEG typically achieves 10:1 compression with little perceptible loss in image quality.Since its introduction in 1992, JPEG has been the most widely used image compression standard in the world and the most widely used digital image format.

29 Tagged Image File Format, abbreviated TIFF or TIF, is a computer file format for storing raster graphics images, popular among graphic artists, the publishing industry,[1] and photographers. TIFF is widely supported by scanning, faxing, word processing, optical character recognition, image manipulation, desktop publishing, and page-layout applications.

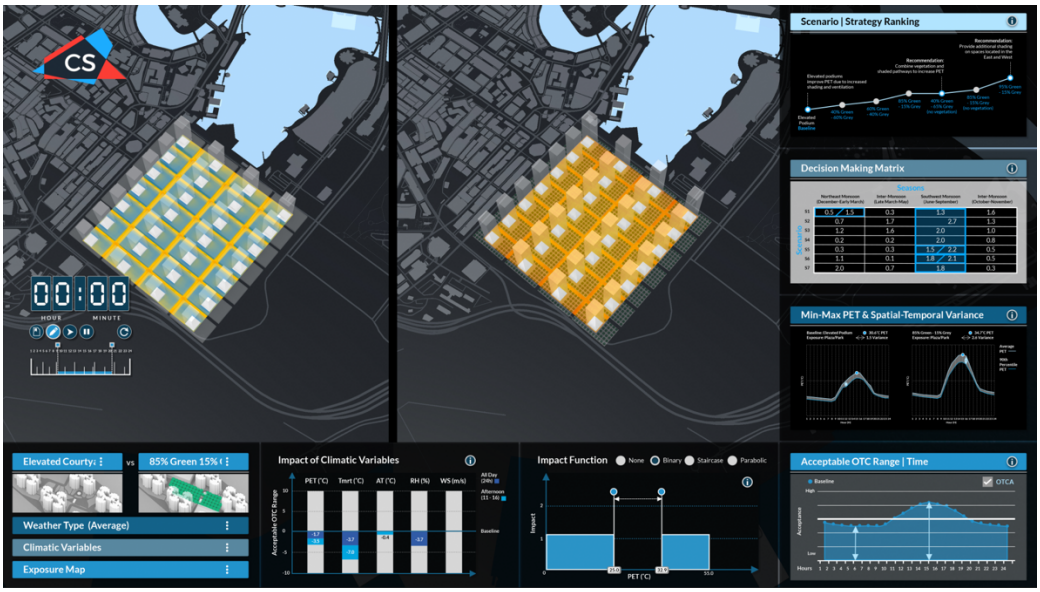
Summary:

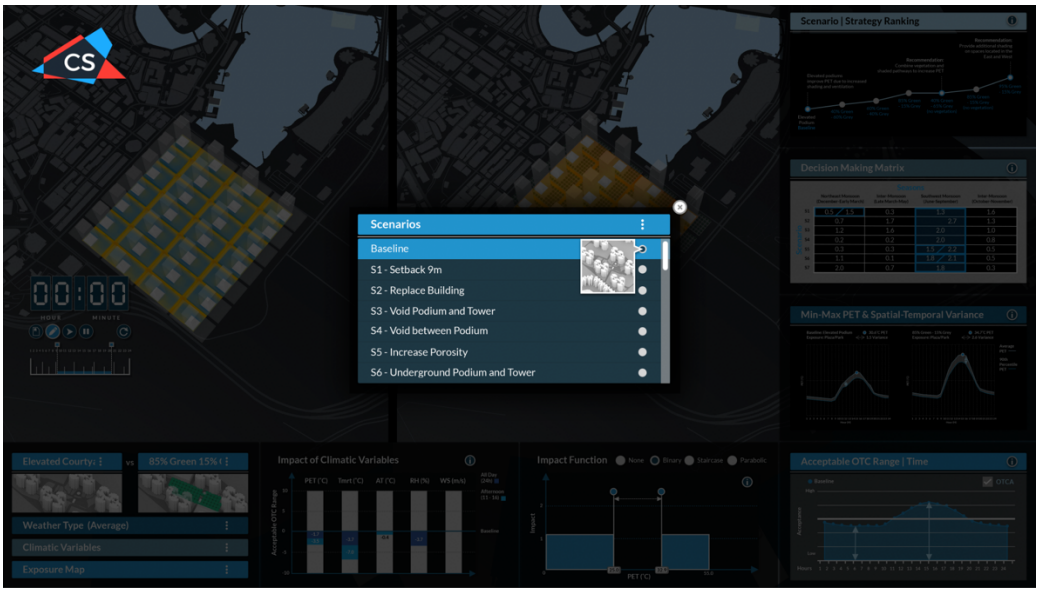
Multiple user(s) have feedback that it would very useful if the DSS could accommodate on-the-fly edits to scenarios. This could be creating new combinations or edits to pre-existing scenarios (e.g., changing existing dimensions or placement of buildings). User(s) commented in having to wait for these 'new' on-the-fly permutation is acceptable. This is a very interesting aspect that we should also consider exploring. This would aspect would prove useful for DSS users as allowing them reins over scenarios not only creates diversity in analysis combinations but also exhibits the versatility of DSS. Some user(s) have suggested an option where interface tools could be custom loaded to their preference. This is likely only useful for user(s) who are more familiar to the platform and require certain specialized tools for their analysis. User(s) have also suggested to have more analysis tools in regards to cost and decision support. Some user(s) have also showed an interest in reviewing more scenarios than the current two. This suggests that the user(s) may desire to review more studies quickly.

For Question 29, two alternative user interface approaches were shown as a mock-up to user(s) to gather their feedbacks and opinions. These two approaches were static image sequences and their movements were explained to the user(s). The overall look and feel is similar to the prototype they were tested on, however the interfaces differed in their usage.

Approach (#2) has the primary components housed at the bottom far left panel as a collapsed accordion. Clicking on the selection would launch a pop-up selection panel for the user to choose from.

Approach (#2)





Question 29: *What is your opinion of the alternative approaches #2 and #3 respectively?*

*Participants' feedback: On **Approach #2***

- User mentioned that #2 is "neater" but not much of a difference from the prototype.
- User appreciates that the interactive elements are now housed together and like that there is a decision matrix panel to explain the breakdown before deriving at the score. However, the climatic variables should also sit with the components panel because it is also interactive.
- Some users have mentioned slight improvement as it is cleaner and likes the new timeline toggle.
- User finds it better, however it may need a summarised note on the foreground of the parameters chosen earlier as they are now hidden in the accordion. Same sentiments about the colour scale.
- User(s) mentioned that segregation between primary parameters with analysis is still needed.
- User said that with the collapsed bar, it looks more concise but the pop-up effect might be distracting and cover too much of the interface. Other user(s) have also said that there may be too much movement. Understandably, user appreciates seeing the panels in a larger form but perhaps this pop-up motion could instead be changed into a slide up motion just above the current panel to reduce coverage of screen and less abrupt movements.

Summary:

Overall, user(s) found the improvements slight. Should the parameters be housed as a collapsed selection in the bottom far left panel, the climatic variables should also similarly be placed there as well. This keeps all the interactive aspects that need user(s) input together. The pop-up effect though better for preview, as it is bigger, may be seen as disruptive as its presence quickly covers the entire screen and its movement seems large. We may need to consider a subtler movement. User(s) have commented that there should still be clear segregation between the different panels. With the inputs now concise in a collapsed selection, the user(s) would still require a summary of what has been chosen made visible to the user(s) at all times for easier reference. This reduces the user(s) effort to recall or back check.

Approach (#3) was done in a sequential manner moving from horizontal tabs left to right. Components/parameters were housed under the tab '1. Components', after selections in that tab are made, tabs 2. Analysis, 3. Benefits and 4. Recommendations respectively progressively move the user forward. Similarly, user(s) can back track to edit any of the selections in tab '1.Components' in which would regenerate analysis of these 'newly' made selections.

Approach (#3)

*Participants' feedback: On **Approach #3***

- User(s) feedback to prefer this approach. It is commented to be more intuitive and that they understand the trade-off for not being all the see all the different panels in a glance (namely the analysis, benefits and recommendation). User added that with the sequential ordered tabs, it is helpful in hinting how to proceed forward in its usage.
- User(s) are aware that with panels not all visible in a glance, minute changes in the analysis might not be obvious. User(s) find this trade-off is acceptable.
- User feedback that it would be good if the panels could be customised after being seasoned into its usage. Further elaborated by the user(s) meaning to keep frequently used panels loaded upon launch and unused panels not be on the interface, thus making it less cluttered.
- User mentioned that perhaps it would also be useful if the different analysis panel could furnish the user(s) with more details when it is clicked to be made bigger.
- User(s) sees more improvement on the interface and think that with the 'i' (information icon) containing explanations on the components would be useful and necessary to the user(s).
- User commented that the camera is currently looking at both scenarios, so when view is being changed, both scenarios move simultaneously. User(s) mentioned that perhaps the scenario should be independent whereby user(s) can lock the view of one scenario while investigating other.
- User suggested that we could consider hiding all panels or have minimising abilities on all the panels instead of having them opened all the time.
- User understands the trade-off of a step by step sequence would cause the user to not be able to see what was chosen in the parameters tab after it is set and move on to see the other tabs and panels. But user still finds the parameter summary would still be necessary for this approach.
- User suggested to allow custom setup the analysis panels. Similar to a library where by the user can decide on the type of analysis they would like to study (e.g., cost, time, temperature) over the score of scenario or mitigation strategies.
- User felt that this approach was intuitive and is the best approach of the two. User could tell what to do next but felt that the timeline (clock) should have hiding abilities.
- User is glad that there is more space devoted for analytical studies and this approach makes for easier understanding as it is sequenced.
- User suggested that it would useful if DSS had a saving or recording mechanism within the software that 'remembers' previously conducted analysis that also performed well. This makes for easier comparison amongst multiple best

performances. As current abilities allows only two comparisons which would derive at one best scenario, with the saved 'history' of multiple best performance, user(s) can make comparison reviewing faster and easier. Especially if there is a large inventory of different scenarios to choose from.

- User mentioned that this approach tells a clearer story of what they are looking at and more systematic in moving forward in analysing data.

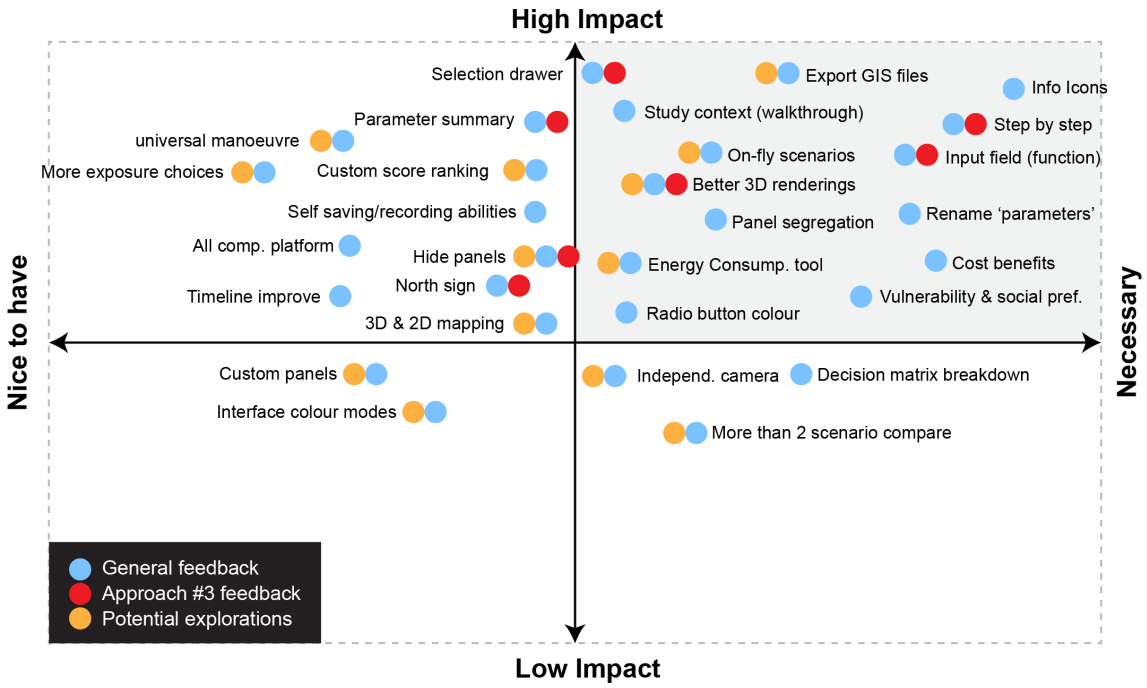
Summary:

Generally, all user(s) feedback that they prefer this approach #3 the best. They find it intuitive and easier to grasp what are the next steps when using the DSS. They understand the trade-off in not being to see the subtle changes in the analysis since the analysis are on separate panels. It is suggested that a summary of the chosen parameter also be necessary. This would make for quicker reference when user(s) are examining the analysis in other tabs. User(s) have also suggested to be able to hide all panels on the interface so as to maximize the visual effect whilst reviewing the 3D space or potentially for presentation. Other areas of exploration include customizable interface panels for frequently used tools and the ability to decide what type of analysis tools the user would load. User(s) have also suggested a camera view locking ability be applied on one of the 3D scenario space whilst investigating another. In short, allowing individual scenario study camera view be independently controlled, as current user maneuvering would apply to both scenario studies on screen. Another useful suggestion from user is a saving history/ recording mechanism of the scenarios analysed. This allows best performance findings be drawn out from within the software history and grants best verses best scenario comparisons quickly.

4.4 Feature Prioritization

The next process after research is to list the features from the quantitative and qualitative data and then prioritise them. As there are a plethora of suggestions, feedbacks and user(s) pain points found in the user survey and usability test, we would first need to plot these features on a simple 2 by 2 axis metric. This feature prioritisation (Diagram) is a 2 by 2 axis metric with the highest to lowest impact (Y-axis) and the necessary to nice to have features (X-axis). Typically, we would execute the features located under the highest impact and necessary quadrant to proceed to the minimum viable product[30] (MVP). As there many data points gathered, only the features deemed necessary, useful and are repetitively advocated would go into the metric.

Diagram 3



These features after plotted would have to be reviewed and decided by the team as to which feature would proceed towards the next prototype based on another two criterion, namely time constraint and its feasibility. Very often, the limitation is that there are datelines to be met, therefore after research, time spent on each phase of design, prototyping and testing would have to also be limited. Naturally, the user(s) needs is the heart of the platform aside from the scientific research but we have to be sensible in which feature we should invest effort and time into executing. As mentioned before, features that are repetitively brought up by user(s) were

[30] *Minimum viable product*
Minimum Viable Product or MVP is a development technique in which a new product is introduced in the market with basic features, but enough to get the attention and meet the functional needs of the users. This is done through tests with users and it makes iterative improvements. The final product is released in the market only after getting sufficient feedback from the product's initial users.

regarded with a fair amount of importance. There are other instances whereby features that are known to be highly regaled but require too much time to pursue at this juncture would be shelved as future features in the continued pipeline. An MVP is progressive and iterative in nature, thus, introducing new or improved features, validating of features and detecting problem areas in tests on the actual user(s) is a common and frequent occurrence.

The following are features deemed necessary, achievable and approved by the team to proceed into prototype two. The user interface assets and platform programming was accomplished concurrently.

- Approach #3 step by step configuration
- Rename terminology “input” to “parameters”
- Context of study (Introduction of study area in reference to Singapore)
- Hide and show panel (Global navigation drawer)
- “I” “?” Icons (Information/Queries icons lead to subject origins, purpose and linkage to objectives)
- Improve visualisation (3D)
- Weather type re-sort categories
- Radio button (reverse treatment)
- Time selection toggle (placement)
- Input field for impact function (toggle)
- Submit button (send request to backend) – developer request
- Calculating progress bar
- Impact of Climatic Variables (Visual distinction Good vs Bad)
- Energy consumption panel hourly and yearly & energy consumption intensity panel hourly and yearly (Additional 4 panels)
- CO_2 emission hourly and yearly and CO_2 emission intensity panel hourly and yearly (Additional 4 panels)
- Cost benefit panel
- Decision support matrix panel (add)
- Summary page of selection (parameters chosen)
- Social preference | Economic preference | Environmental preference (Strategies score ranked in ascending order)

4.5 DSS platform creation

The developed DSS is a faithful implementation of the research and development processes and their subsequent actions outlined in previous chapters.

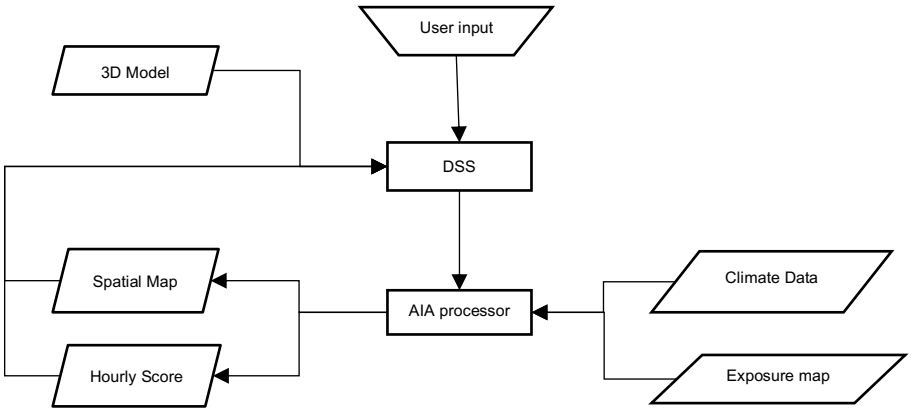
The DSS has been developed as a stand-alone, 3D accelerated desktop application running under Windows and/or MacOS operating systems. Due to its heavy use of 3D graphics, it is based on the Unity game engine and C# programming language.

Initially, the DSS has been developed as an offline application, meaning the rendering and calculations were all done on user's computer. But as the Cooling Singapore research project has progressed, changing the system hierarchy from having a local standalone software to cloud based frontend/backend hierarchy has resulted in substantial change in the architecture of the DSS application. Section 4.5.1 describes this in detail. Section 4.5.2 shows the status of prioritized feature based on the useability tests as outlined in Chapter 4.4.

4.5.1 System Hierarchy

The new hierarchy contains a frontend for data visualization and user interaction, a backend to store data and calculate statistical results from stored data. The backend is implemented by Dr Heiko AYDT as part of Work Package 3 of Cooling Singapore. This hierarchy has two main advantages. First, it offloads the computational intensive part from users personally computer. Secondly, users do not have to store a large amount of data in their hard drive.

The following graph shows the work flow of the frontend backend hierarchy. Users select parameters from on the DSS interface then send the selection to the backend. The AIA processor in the backend takes corresponding data from the server and calculation spatial map and/or hourly scores to return to the frontend. Then the frontend visualizes the results in charts, graphics and heatmaps with 3D models.



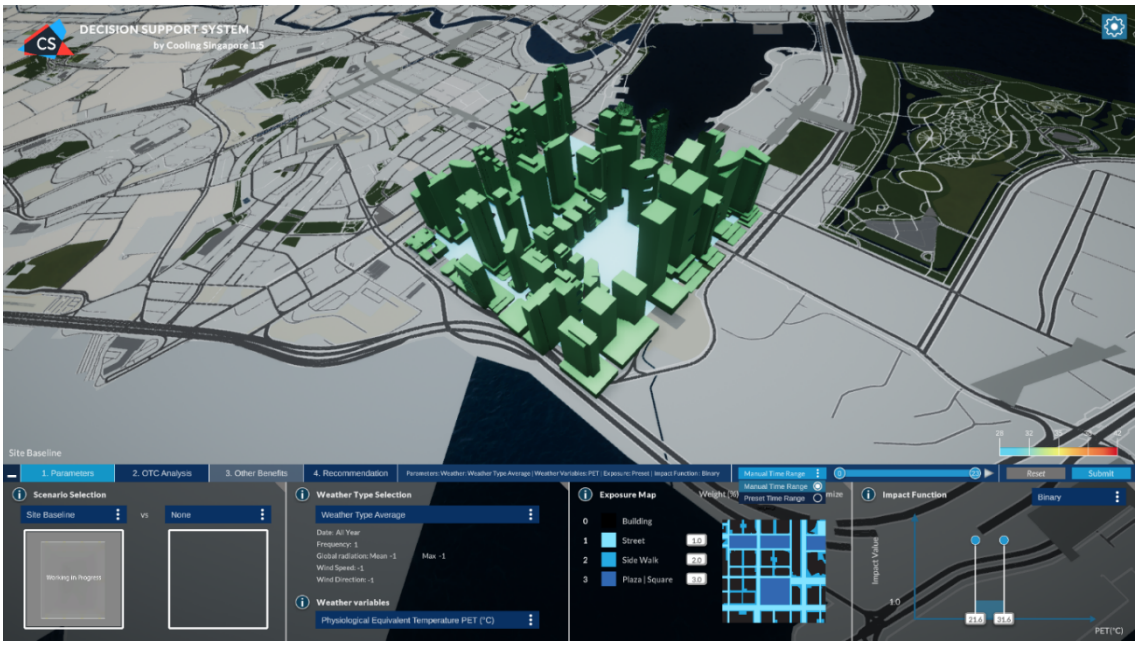
4.5.2 Implementation status of prioritized features

The following chapter focuses solely on the developed implementation of the prioritized features outlined in Chapter 4.4 based on outcomes of the useability tests.

- ***Feature: Approach #3 step by step configuration***

  Status: Implemented

  Description: The implementation created four tabs for four panels on the bottom of the screen. Each tap has a number to indicates the sequence of the selection. Users can start from setting parameters on the first tab. After that, they can view OTC analysis result, Other benefit and Recommendation to make a decision.



- ***Feature: Rename terminology "input" to "parameters"***

  Status: Implemented

- ***Feature: Context of study (Introduction of study area in reference to Singapore)***

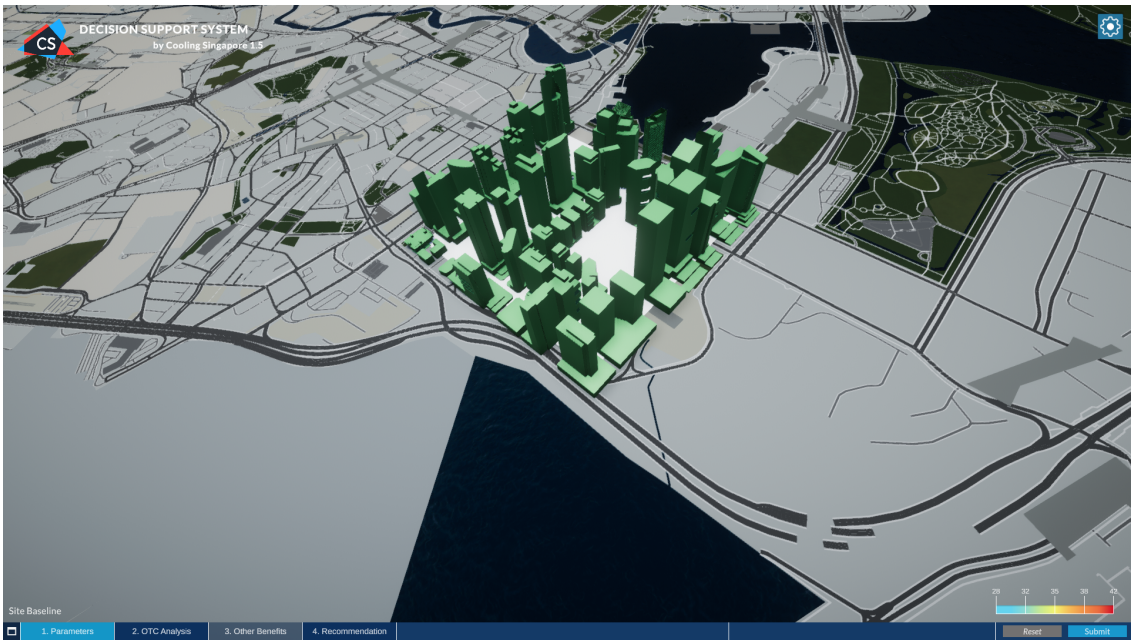
  Status: Implemented

  Description: A Singapore map with 3D city models has been placed as the background. Each study site is manually placed on the map. A pin point is placed to indicate the name and position of each study site. Users can click the pin point to zoom in one site and analyze the simulation result of the site.

- ***Feature: Hide and show panel (Global navigation drawer)***

  Status: Implemented

  Description: Two types of minimize the panel are implemented. First, the panel will be shown when users switch from site selection view to site analysis view. When they switch back the site selection view, panel will be hidden. Secondly, users can also minimize the panel using the minimize button when they are in the site analysis view. The following picture shows the minimized the panel with the tab area.



- ***Feature: "I" "?" Icons (Information/Queries icons lead to subject origins, purpose and linkage to objectives)***
  Status: Implemented

- ***Feature: Improve visualisation (3D)***
  Status: Implemented
  Description: Two main strategies are used to improve the visualisation quality. First, a post-processing volume enables Color grading, Bloom and Ambient Occlusion. Those algorithms give a general good look and feel to the 3D space. Secondly, a Singapore city model with more details has been purchased from online modeler[31]. The model can be rendered using solid rendering.

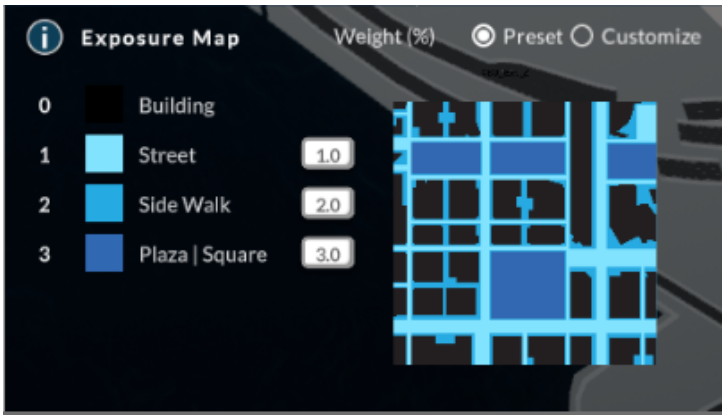
- ***Feature: Weather type re-sort categories***
  Status: Implemented

- ***Feature: Radio button (reverse treatment)***
  Status: Not Implemented
  Description: Radio button is not used in this version.

- ***Feature: Time selection toggle (placement)***
  Status: Implemented
  Description: Time selection can be switched between manual range and pre-set ranges. Manual range allows users to drop a double side slider to specify the range. Pre-set ranges defined

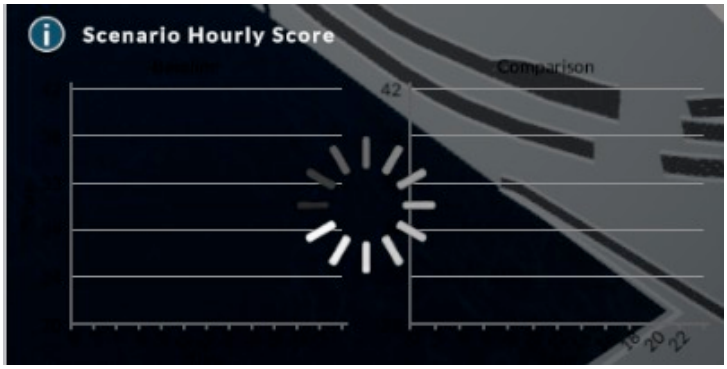
- ***Feature: Input field for impact function (toggle)***
  Status: Implemented
  Description: Two types of impact functions can be toggled. Pre-set function will fill the impact values with 1.0, 2.0 and 3.0 according to Ido's formula. Those values are non-changeable. Custom impact function allows users to input the value they want to experiment with. Currently there is no limitation for the customized values. A sum up to one checking may be implemented later to limit the input.

[31] https://www.cgtrader.com/3d-city-models



- ***Feature: Submit button (send request to backend) – developer request***
  Status: Implemented
  Description: To avoid submitting too much redundant requests to the backend, a submit button is included to allow users to submit their selected parameters.

- ***Feature: Calculating progress bar***
  Status: Implemented
  Description: As the backend calculation status cannot be retrieved at this stage, an infinity spiral is selected as the progress indicator. When a request is send to the backend, the spiral will be shown until frontend received the result. The following image shows a progress bar.



- ***Feature: Impact of Climatic Variables (Visual distinction Good vs Bad)***
  Status: Implemented

- ***Feature: Energy consumption panel hourly and yearly & energy consumption intensity panel hourly and yearly (Additional 4 panels)***
  Status: Work in progress

- ***Feature: CO_2 emission hourly and yearly and CO_2 emission intensity panel hourly and yearly (Additional 4 panels)***

  Status: Work in progress

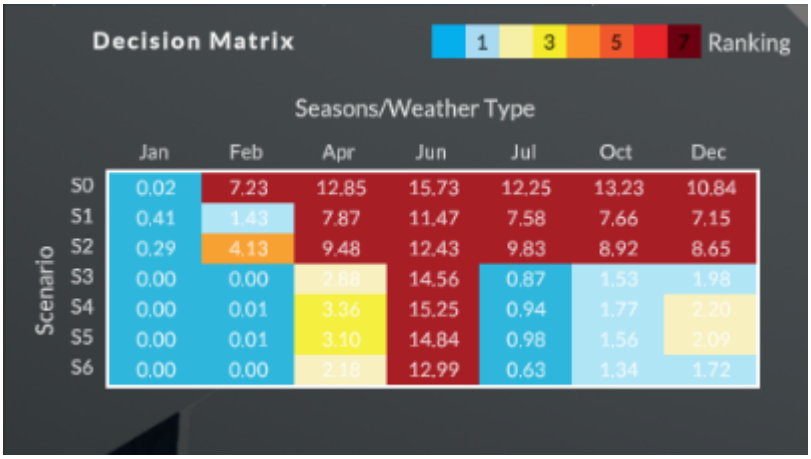
- ***Feature: Cost benefit panel***

  Status: Work in progress

- ***Feature: Decision support matrix panel (add)***

  Status: Done

  Description: The decision support matrix shows score for 7 weather types for 7 scenarios. Users can compare them directly. It currently only supports PET as only PET has calibrated impact function.



- ***Feature: Summary page of selection (parameters chosen)***

  Status: Work in progress

- ***Feature: Social preference | Economic preference | Environmental preference (Strategies score ranked in ascending order)***

  Status: Work in progress

- ***Feature: Panel enlarge***

  Status: Implemented

  Description: Now panels for each chart or input parameters can be enlarged to show on the centre of the screen. This may help users to view the contain more clearly.

- ***Feature: Parameter status bar***

  Status: Implemented

  Description: A status bar is added to the panel to remind users the selected parameters.

- ***Feature: Setting button***

  Status: Implemented

  Description: Setting button enables 4 buttons. They are functional as exit button, escape from full screen mode, reset camera to original view and return to the map view.

5 Conclusions

5.1 Summary of findings

The findings show that beyond the establishment of persona(s) researcher and upper management user(s), we have also discovered sub-persona(s) based on seniority and the various research speciality they are tasked with. The public user was not validated as they were not included in this phase of the study. We have amassed valuable data both quantitatively and qualitatively on the improvement of usage, expectation and problem areas to be address on the DSS platform. In accordance to what was necessary, useful and feasible within the time constraints, the feature prioritisation helped informed the decision on what would proceed into the next prototype. To validate whether these improvements are indeed successful in meeting the needs of the user(s), greater engagement with the planning and scientific team would be required. This continuous iterative effort in surveying and testing the prototype usability on actual user(s) would contribute in building a robust platform. The feedback collected and described in this report was used to further improve and advance the development of the DSS platform.

The topic of developing a Decision Support System for research purposes and its direct uses is more thoroughly described by the Cooling Singapore team in the following publications: "Recommendation system for climate informed urban design under model uncertainty." [32], "*A decision support tool for climate-informed and socioeconomic urban design*." [33] and "*A novel decision support tool for climate-responsive urban design."* [34] These publications go beyond the scope of this technical report, nevertheless they are complimentary to it.

---

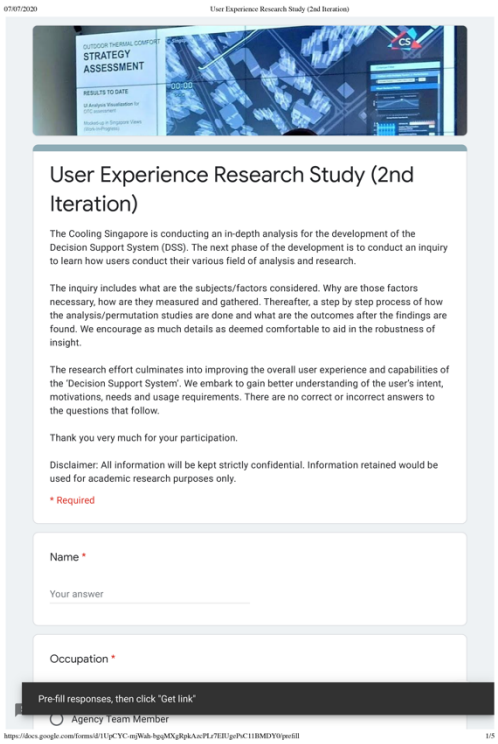
[32] *Nevat, Ido, Lea A. Ruefenacht, and Heiko Aydt. "Recommendation system for climate informed urban design under model uncertainty." Urban Climate 31 (2020): 100524.*

[33] *Nevat, Ido, et al. "A decision support tool for climate-informed and socioeconomic urban design." Environment, Development and Sustainability (2020): 1-25.*

[34] *Zhong, Sailin, et al. "A novel decision support tool for climate-responsive urban design." Journal of Physics: Conference Series. Vol. 1343. No. 1. IOP Publishing, 2019.*

6 Glossary

User Survey Analysis



07/07/2020 User Experience Research Study (2nd Iteration)

STRATEGY ASSESSMENT

RESULTS TO DATE

User Experience Research Study (2nd Iteration)

The Cooling Singapore is conducting an in-depth analysis for the development of the Decision Support System (DSS). The next phase of the development is to conduct an inquiry to learn how users conduct their various field of analysis and research.

The inquiry includes what are the subjects/factors considered. Why are those factors necessary, how are they measured and gathered. Thereafter, a step by step process of how the analysis/permutation studies are done and what are the outcomes after the findings are found. We encourage as much details as deemed comfortable to aid in the robustness of insight.

The research effort culminates into improving the overall user experience and capabilities of the 'Decision Support System'. We embark to gain better understanding of the user's intent, motivations, needs and usage requirements. There are no correct or incorrect answers to the questions that follow.

Thank you very much for your participation.

Disclaimer: All information will be kept strictly confidential. Information retained would be used for academic research purposes only.

* Required

Name *

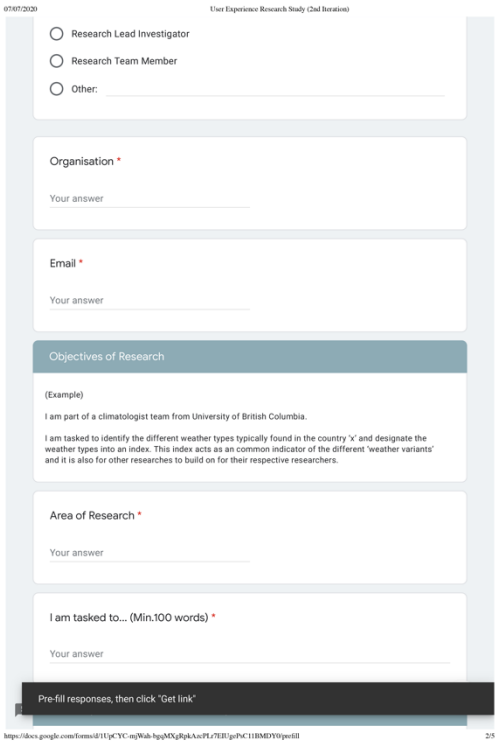
Your answer

Occupation *

Pre-fill responses, then click "Get link"

Agency Team Member

https://docs.google.com/forms/d/1UpCYC-mjWab-bgqMXgRpkAxcPLz7EIU/gcPsC11BMDY0/prefill 1/5



07/07/2020 User Experience Research Study (2nd Iteration)

Research Lead Investigator

Research Team Member

Other:

Organisation *

Your answer

Email *

Your answer

Objectives of Research

(Example)

I am part of a climatologist team from University of British Columbia.

I am tasked to identify the different weather types typically found in the country 'x' and designate the weather types into an index. This index acts as an common indicator of the different 'weather variants' and it is also for other researches to build on for their respective researchers.

Area of Research *

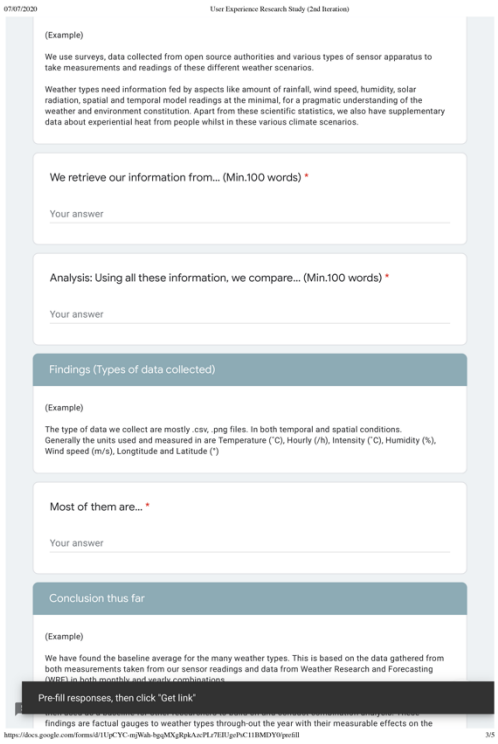
Your answer

I am tasked to... (Min.100 words) *

Your answer

Pre-fill responses, then click "Get link"

https://docs.google.com/forms/d/1UpCYC-mjWab-bgqMXgRpkAxcPLz7EIU/gcPsC11BMDY0/prefill 2/5



07/07/2020 User Experience Research Study (2nd Iteration)

(Example)

We use surveys, data collected from open source authorities and various types of sensor apparatus to take measurements and readings of these different weather scenarios.

Weather types need information fed by aspects like amount of rainfall, wind speed, humidity, solar radiation, spatial and temporal model readings at the minimal, for a pragmatic understanding of the weather and environment constitution. Apart from these scientific statistics, we also have supplementary data about experiential heat from people whilst in these various climate scenarios.

We retrieve our information from... (Min.100 words) *

Your answer

Analysis: Using all these information, we compare... (Min.100 words) *

Your answer

Findings (Types of data collected)

(Example)

The type of data we collect are mostly .csv, .png files. In both temporal and spatial conditions. Generally the units used and measured in are Temperature (°C), Hourly (/h), Intensity (°C), Humidity (%), Wind speed (m/s), Longitude and Latitude (°)

Most of them are... *

Your answer

Conclusion thus far

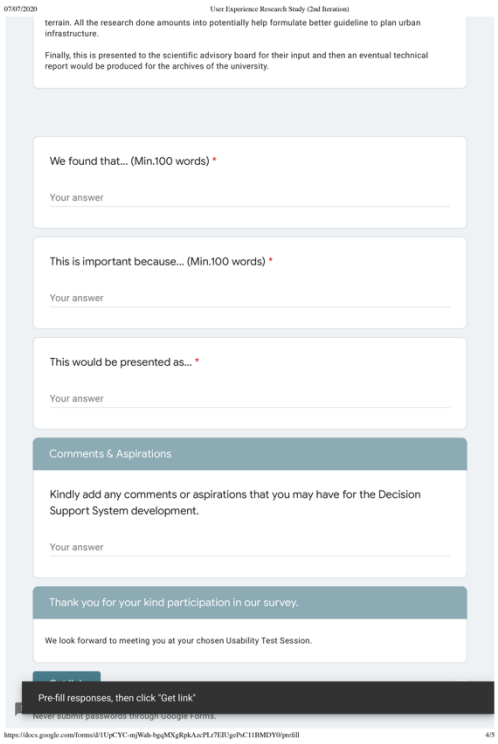
(Example)

We have found the baseline average for the many weather types. This is based on the data gathered from both measurements taken from our sensor readings and data from Weather Research and Forecasting (WRF) in both monthly and yearly combinations.

Pre-fill responses, then click "Get link"

findings are factual gauges to weather types through-out the year with their measurable effects on the

https://docs.google.com/forms/d/1UpCYC-mjWab-bgqMXgRpkAxcPLz7EIU/gcPsC11BMDY0/prefill 3/5



07/07/2020 User Experience Research Study (2nd Iteration)

terrain. All the research done amounts into potentially help formulate better guideline to plan urban infrastructure.

Finally, this is presented to the scientific advisory board for their input and then an eventual technical report would be produced for the archives of the university.

We found that... (Min.100 words) *

Your answer

This is important because... (Min.100 words) *

Your answer

This would be presented as... *

Your answer

Comments & Aspirations

Kindly add any comments or aspirations that you may have for the Decision Support System development.

Your answer

Thank you for your kind participation in our survey.

We look forward to meeting you at your chosen Usability Test Session.

Pre-fill responses, then click "Get link"

Never submit passwords through Google Forms.

https://docs.google.com/forms/d/1UpCYC-mjWab-bgqMXgRpkAxcPLz7EIU/gcPsC11BMDY0/prefill 4/5

Usability Test Analysis4.3

07/07/2020 Usability Test Feedback

Usability Test Feedback

Hello. Thank you for participating in our usability test. This is an effort to improve the overall user experience and capabilities the Decision Support System (DSS). To discover and understand user intent, motivations, needs and usage habits. There are no correct or incorrect answers to the questions.

The inquiry includes what are the subjects/factors considered, a step by step process of how analysis/ permutation studies are done and what are the potential outcomes of these findings. We encourage as much detail as deemed comfortable to facilitate insight.

Please note that this is a preliminary prototype and therefore a work-in-progress.

Disclaimer: All information will be kept strictly confidential. Information retained would only be used for academic research purposes only. Thank you for your kind participation.

Please provide us with the following details before we begin:

* Required

Name *

Your answer

Occupation *

- Agency Group Lead
- Agency Team Member
- Research Lead Investigator

Pre-fill responses, then click "Get link"

https://docs.google.com/forms/d/1MXp4C9Jd1wu0n8HAv-AD488-Ua7a0LQnbEC5f9NmuF7o/prefill 1/8

07/07/2020 Usability Test Feedback

Organisation *

Your answer

Email *

Your answer

Task one: interface introduction

Short answer feedbacks and single ease questions (1 'Yes, it is apparent') to (5 'No, it is not immediately apparent')

Does the interface provide an impression of its purpose? *

	1	2	3	4	5	
Yes	○	○	○	○	○	No

Does the interface provide clarity of its components? *

	1	2	3	4	5	
Yes	○	○	○	○	○	No

Pre-fill responses, then click "Get link"

https://docs.google.com/forms/d/1MXp4C9Jd1wu0n8HAv-AD488-Ua7a0LQnbEC5f9NmuF7o/prefill 2/8

07/07/2020 Usability Test Feedback

Does the interface appear to have a sequential order? *

	1	2	3	4	5	
Yes	○	○	○	○	○	No

Any thoughts/ suggestions on how it should appear? *

Your answer

What is your opinion of the interface? (Aesthetics)

Your answer

Task two: navigation introduction

Short answer feedbacks and single ease questions (1 'Yes, it is acceptable') to (5 'No, it is not ideal')

How do you feel about the movement latency? (Speed of movement) *

	1	2	3	4	5	
Yes	○	○	○	○	○	No

How do you feel about the movement dexterity? (Manoeuvring smoothness) *

	1	2	3	4	5	
Yes	○	○	○	○	○	No

Pre-fill responses, then click "Get link"

https://docs.google.com/forms/d/1MXp4C9Jd1wu0n8HAv-AD488-Ua7a0LQnbEC5f9NmuF7o/prefill 3/8

07/07/2020 Usability Test Feedback

How do you feel about the overall negotiation of 3D space? *

	1	2	3	4	5	
Yes	○	○	○	○	○	No

Any thoughts/ suggestions on how it should be? *

Your answer

Task three: usage and analysis

Short answer feedbacks, multiple choice questions, single ease questions (1 'Yes, it is acceptable') to (5 'No, it is not ideal')

Does the visual depiction provide a context of what you are reviewing? *

	1	2	3	4	5	
Yes	○	○	○	○	○	No

To begin analysis, you would first need to pick your primary selections. Which terminology are you more likely to identify with of this notion? *

- [ ] Components
- [ ] Input
- [ ] Parameters
- [ ] Criterion
- [ ] Other:

Pre-fill responses, then click "Get link"

https://docs.google.com/forms/d/1MXp4C9Jd1wu0n8HAv-AD488-Ua7a0LQnbEC5f9NmuF7o/prefill 4/8

Your answer

Do you work primarily with weather types specified independently or seasons stipulated by Meteorological Service Singapore (MSS)? *

Your answer

What do you understand from the phrase 'exposure map'? *

Your answer

There are three different exposure areas on the interface: street, sidewalk, plaza/park. In the planning and design of districts, are there also other exposure areas considered? *

Your answer

Task three: usability setup - one

Note: The lesser the PET, the cooler and better it is. The higher the wind, the cooler and better it is.

Set values to the following for analysis:

1) Scenario Selection: 'Setback 9m'
2) Weather Type: 0
3) Climatic Variables selection: PET
4) Exposure Map: Unweighted
5) Impact function: Binary, Showing PET temperatures between (25.0˚C to 39.0˚C)
6) Timeline to: 7am to 6pm

What is the overall PET score for the scenario 'Setback 9m'? *

Your answer

Pre-fill responses, then click "Get link"

('Setback 9m') At what time is the PET score at its highest at 0.971? *

Your answer

Task three: usability setup - two

With the same scenario, add the following for analysis:

1) Scenario: add comparison 'Void through Podium'
2) Change timeline to 10am to 6pm
3) Impact function: Binary, Showing PET temperatures between (24.0˚C to 39.0˚C)
3) Manoeuvre visual space to profile view

Of the two scenarios chosen, which faired the best? *

Your answer

At what time did both scenario PET reading peaked at its worst? *

Your answer

Task three: usability setup - three

Set values to the following for analysis:

1) Scenario Selection: 'Void through Block' vs '66% Greening'
2) Weather Type: 4
3) Climatic Variables selection: PET
4) Exposure Map: Unweighted
5) Impact function: Binary, Showing PET temperatures between (24.0˚C to 30.0˚C)
6) Timeline to: 6am to 8pm

Pre-fill responses, then click "Get link"

Among all the scenarios, which scenario PET scored the worst? *

Your answer

Please rank the following in accordance to your priorities *

- [ ] Outdoor thermal comfort (PET)
- [ ] Wind Speed and direction
- [ ] Mean radiant temperature
- [ ] Air temperature
- [ ] Relative humidity
- [ ] Energy saving
- [ ] CO2 Emissions
- [ ] People Preference
- [ ] Investment, maintenance, operational costs
- [ ] Other: _____

Interests, feedbacks and insights

What are the areas of interest in your analysis? *

Your answer

How do you and the team conduct the analysis required for your interest areas? *

Your answer

Pre-fill responses, then click "Get link"

Your answer

Static DSS Visual Approaches #2 and #3

Show and walk user through the sequence of usage and interface display. (Static Visual)

What is your opinion of the alternative approaches #2 and #3 respectively? *

Your answer

Get link

Never submit passwords through Google Forms.

Pre-fill responses, then click "Get link"