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# Experimental Research with Computer Simulation (Case Study of *Urban Cool Island*)

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**ABSTRACT**

This research will describe experimental research methodology using computer simulation with the case study of urban cool island research. The urban cool island is one of the urban heat island mitigation technology strategies. This technology uses a geometric and material intervention process that forms an urban cool island in an area with high urban heat island intensity. The urban cool island will expand and reduce the temperature of the hot islands so that the urban heat island gets smaller. In the research process, a series of experimental methodologies were carried out. Experimental methodology is carried out on a regional scale will be difficult and expensive. So a computer simulation is needed to facilitate urban cool island experiments in the area. The stages of experimental research with computer simulations use two process stages (1) Quasi-measurement experiments and field observations in the UCI area, (2) Validation of field measurements versus simulation models, (3) Experiments with computer simulations by creating test models and comparison models. The scope of research on the scale of urban areas with experimental methodology becomes efficient with the help of computer simulations. In *Urban Cool Island*, several countries have also used this methodology. Computer simulation used: ENVI-MET, CFD-Ansys, and others. Before starting the research, a clear frame or research design is needed, determining variables, replicating the real conditions, mastering the use of simulations, and always paying attention to the results, which are continuously controlled and validated to produce simulations that are close to the real conditions.

Keywords: experimental, computer simulation, urban cool island

## 1. Introduction

### Experimental Research Design with Computer Simulation

### Experimental Design Experimental

Research is research that departs from the philosophy of positivism. The experimental research design frame begins with a hypothesis or prediction of the answer to a research question. Then in the process of answering the research, tested in experiments with certain interventions and modifications in several alternatives. The intervention is in the form of variables that are replaced and tested based on the theories and hypotheses that are built. The results of experimental research are in the form of quantitative data whose results will be compared and then selected to provide answers to exploratory hypotheses. [1]

The research examines the cause and effect of a condition, the advantages of which can give results that are close to true, and measurable. Each data result can be clearly identified. When conducting experiments, it is necessary to design a simplification of the model from a very complex actual condition. Observations are designed according to the phenomena that exist in nature. Researchers must consciously control

the model in the experiment, combine and select variables that are relevant to the theory, delete irrelevant, and unimportant variables for the causal hypothesis that is compiled. The designed experimental model or condition focuses on predetermined variables, and may not be found in the real world. The experimental stages can be seen in Figure 1.

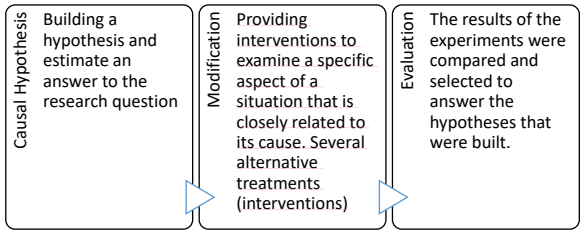


Figure 1: Stages of experimental research

In experimental research, a systematic procedure is designed first. The steps for this experimental research are as follows:

- Determining the topic, defining the research problem to be tested, and developing a hypothesis with predetermined variables according to the theory.
- Planning experimental research design: experimental stages, systematic testing of experiments in parallel or sequentially, temporary or independent testing, number of experiments (models to be intervened), number of experimental dependent variables, number of dependent variables, and stages of intervention instructions that are quite clear.
- Measuring of the pretest before the intervention variable, and the measurement after the intervention variable or post-test.

In certain studies, tools for experiments can use the help of computer simulations. This is very helpful to simplifying the actual conditions and then can provide more varied interventions and optimal results. Especially if the scope of research is broad and on a large scale. For example, the scope of building design and urban areas. Before explaining in more detail, the *Urban Cool Island* research using experimental research methods assisted by computer simulations, the next subsection will explain the research with simulations.

Simulation research is research with a broader effort to replicate (mimesis, or imitation) an object and setting conditions from real-world conditions. Philosophically, Plato reminds us that simulation can be a manipulation of a replica of reality. The main purpose of the simulation is to create a replica of the reality of a condition. The next major challenge is how to accurately approach the replica in real conditions. At the time of making a replica, control what variables are ignored or missing, variables that still exist or must exist from the real condition. One of the simulation research projects uses computer simulation, before using the simulation it must be validated first. This is to find out whether computer simulation can be used as a test tool that is close to real conditions. Validation is done by measuring and observing the field, then making a replica model according to real conditions, the next step is observing the results in the field and simulation. Then the computer simulation program that has been validated can be used by creating a model with a predetermined variable intervention. [2] An illustration of experimental research assisted by computer simulation can be seen in Figure 2. Globally, this illustration depicts *Urban Cool Island*.

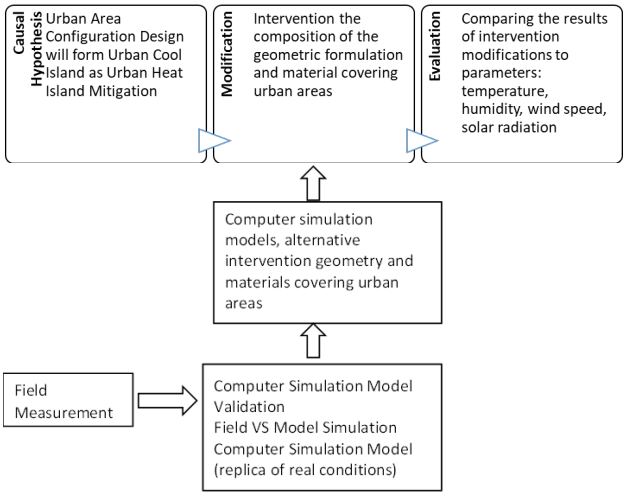


Figure 2: Research Stages *Urban Cool Island* Mitigation *Urban Heat Island* with experimental methodology assisted by computer simulation

## 2. Study *Urban Cool Island* and Its Application

*Urban Cool Island* is the condition of urban areas in the form of circles or islands where the temperature is cooler than the surrounding environment. This is the opposite of *Urban Heat Island*. *Urban Heat Island* itself is isotherm heat contours that are formed due to the same hot temperature. If *the Urban Heat Island* is not addressed, the *Urban Heat Island* will expand and will have a negative impact on city conditions (ecology, health, and *wild weather*) [1]. To reduce the intensity of *Urban Heat Island* with a heat mitigation strategy, one of the strategies with *Urban Cool Island* [2]

Figure 3 shows the intensity contour of the *Urban Heat Island* in urban areas. If the conditions of the *Urban Heat Island* are not addressed, the intensity of the *Urban Heat Island* will have the potential to be wider and will make the city's warming even higher [4] in his research provided an *Urban Cool Island* in the form of a court-yard (garden or green roof) in one area. This intervention provides a low intensity of *Urban Heat Island* or cooling of urban areas (*Urban Cool Island*). From the *Urban Cool Island* , there will be an increase in air movement to the *Urban Heat Island* high-intensity *urban heat island*. If the geometry and land cover material can be designed in such a way as to form b*reeze way* intensity *Urban Heat Island* . More details can be seen in Figure 4.

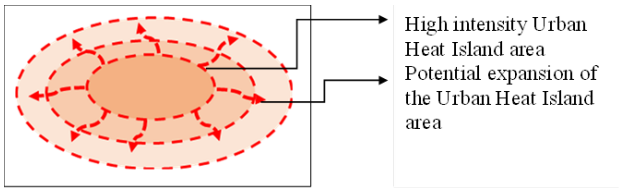


Figure 3:The urban heat island contour area is high intensity and has the potential for expansion of the urban heat island.

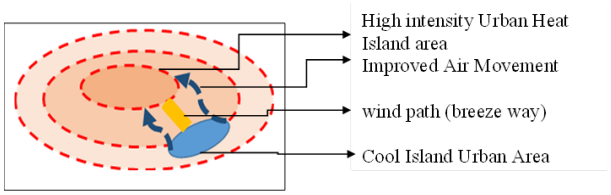


Figure 4: Urban Cool Island intervention in the Urban Heat Island area.

The *Urban Cool Island* study is an urban area-scale study, with a focus on the observation of cooling conditions in urban areas. factors forming the *Urban Cool Island* are the urban configuration which consists of two variables: geometry and material of urban area cover (*hardscape, softscape*, and water bodies) [5] [6]. Changes in these factors will change the parameters of *Urban Cool Island* in urban areas: temperature, wind speed, humidity, and solar radiation. [3]. Changes in the right factors forming the *Urban Cool Island*, can increase wind speed [7] [8], decrease solar radiation gain [4] [10], and ultimately reduce the temperature of urban areas so that cooling of urban areas is achieved.

The application of *Urban Cool Island* research is through an experimental research process assisted by computer simulations. In the experimental research process, the intervention is carried out by changing the factors that make up the *Urban Cool Island*: the geometry and material of the urban cover. In this study,

changing this intervention is easier to do with the help of computer simulations. This computer simulation assistance is also more flexible, efficient, and can allow variations in intervention modification. The computer simulation in the *Urban Cool Island* at the initial stage replicated the real conditions, then compared it with measurements and field observations as validation of the computer simulation. Then in the next stage changing the variables, and then the results from the simulation are compared to get optimal results.

## 3. Experimental Research Design and *Urban Cool Island*

Before conducting experimental research assisted by computer simulations for *Urban Cool Island*, in the initial step, a clear research framework has been defined: topics, research questions, hypotheses, variables, and parameters. And have chosen what simulation will be used for this research. Therefore, before starting the research, the theory about *Urban Cool Island* has been clearly explored. This is for determining variables and hypotheses as well as research limitations. This research limitation serves to create a replica or computer simulation model and simplify the actual conditions. The next step is to make a research design with what stages will be carried out. For this research, the stages are divided into two stages, namely quasi-experimental and pure experiment. Quasi-experiments are measurements and field observations. Observing the causal relationship between *Urban Cool Island* and its parameters. While the second stage is as described above regarding computer simulation research, it is necessary to validate computer program simulations. The steps and design of the *Urban Cool Island* detail can be seen in Table 1.

Table 1: Steps and design of experimental research assisted by simulation

| Research Steps | Subject | Information |
|---|---|---|
| Topics | Thermal Environment | Urban Heat Island Mitigation |
| Research question | What is the formulation of the geometry and materials covering urban areas for the formation of Urban Cool Island? | |
| Hypothesis | Geometry and the right area cover material can form an Urban Cool Island (urban heat island mitigation) | |
| | Variable | Urban area configuration<br>Urban area geometry<br>Urban area cover material |
| | Parameter | temperature<br>Humidity<br>Solar Radiation<br>Wind velocity |
| | Determination of data collection tools, experiments, and computer simulations | Aerial photography (Remote sensing)<br>ENVI MET<br>Computational Fluid Dynamics (CFD) |
| Experimental Research Design | Stage 1: Quasi Experiments | |
| | a. Collection of aerial photographs (remote sensing) | Identification and selection of field measurement locations |
| | b. Field measurements and observations | Observation of variables and parameters |
| | Stage 2: Pure Experiment | |
| | a. Making a model of existing conditions according to field conditions. | Computer simulation validation (ENVI MET and CFD) |
| | b. Creating a model with predefined | Geometry and material intervention |

| Research Steps | Subject | Information |
|---|---|---|
| | variable interventions. | model of urban area coverage on ENVI MET and CFD |
| | c. Evaluating and comparing results | Observation of the forming parameters of Urban Cool Island |

The research was designed in two experimental stages, namely the quasi-experimental stage and the purely experimental stage. The research stage is in the form of a sequential stage, the first stage is completed, and then the second stage. The procedure design is as follows:

1. The first stage is the stage of quasi-experimental research, this stage focuses on measuring and collecting data on field conditions or actual conditions,

   a. Collection of aerial photos from remote sensing in a certain area.
   b. Identify aerial photographs for determining the location of field measurements. The location determined is a location with a high-intensity urban heat island and a low-intensity urban heat island (urban cool island)
   c. Field measurements at predetermined locations from aerial photo identification.
   d. In addition to measurements, field observations were also made on the variables of Urban Cool Island factors: urban configuration (geometry and material covering urban areas) on the influence of Urban Cool Island parameters (temperature, humidity, wind speed)

The second stage is a purely experimental stage, at this stage is a stage of using computer simulation as an experimental tool. The computer simulation used is ENVI MET and CFD. Previously, the computer simulation program was validated with field conditions. After being validated, it was then used for experimentation by providing an intervention with the *Urban Cool Island*.

1. Making a replica of the simulation model, and validating from the field measurements with simulation.
2. Making a model by providing an intervention with the *Urban Cool Island*, namely the configuration of the urban area (geometry and material of the urban area cover) to the parameters of the *Urban Cool Island* (temperature, humidity, wind speed, and solar radiation gain).
3. Comparing the results of the data from computer simulations of the modified model that has been intervened.

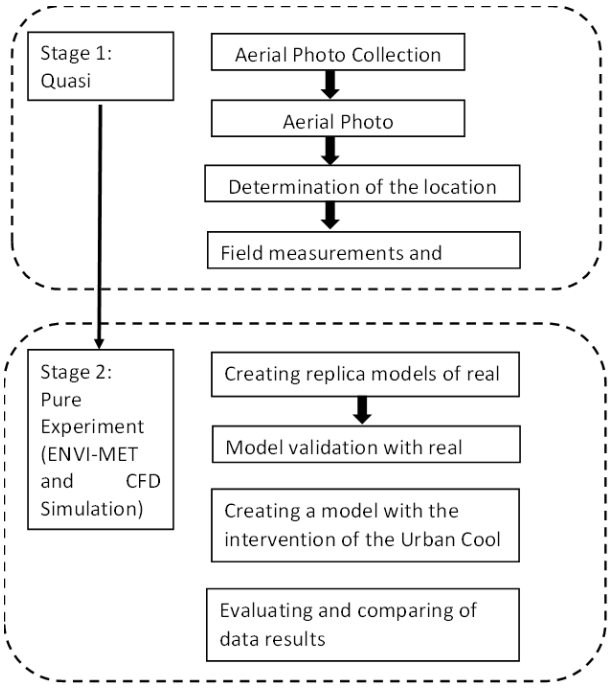


Figure 5. Chart of the stages of the Urban Cool Island experimental research method

In the research process using experimental methods assisted by computer simulations, it takes the ability of researchers to understand the substance and good theory. Researchers must be able to choose the variables used and ignored, field conditions used and ignored, which will be replicated in the experimental model. Another ability is the ability to interpret

maps and aerial photographs, this ability is very important to identify and analyze the intensity of *Urban Heat Island* in urban areas. And another important ability is the ability to use ENVI MET and CFD simulations as experimental tools and to replicate field conditions in computer simulations. The initial stage of using computer simulation is validating phenomena in the field and computer simulation. This validation process sometimes takes a long time. In the process, whether to change the simplification of the model or decide whether to use this simulation or replace it with another simulation.

## 4. **Research Precedent *Urban Cool Island***

Research on *Urban Cool Island* mitigation *urban heat island has* been done a lot. And all of these studies used the methodology of computer-assisted experiments. The factors that make up the *Urban Cool Island* that are reviewed are generally the configuration of urban areas, and the factors are divided into two, namely: (1) Geometry of urban areas and, (2) urban area cover materials. There are researches as a whole with variable factors: urban configuration, [8] [11] [5] [3], but there are also studies with one factor variable: geometry of urban areas [7] [12] [13] [14] [15] [16]. As well as other factors, namely the urban area cover material in the form of roofing material [17] [18], pavement material [5][19] [22] [20], [21], wall material, [22],and *softscape* [9],[23],[24] 25]. *Urban Cool Island* research with complex and partial variable factors, all using computer simulation-assisted experimental methods. The computer simulation used depends on the parameters that will be evaluated from the formation of the *Urban Cool Island*.

Leone (2018) in his research, intervened in the formation of an *Urban Cool Island* by covering urban areas in the form of green land, namely *courtyards*, which were designed in the form of gardens and green roofs. The factor for the formation of *Urban Cool Island* is to find out the parameters for obtaining solar radiation which will affect the temperature reduction in urban areas. Then the computer simulation used is ENVI MET [5]. ENVI MET simulation is also used for other cover material interventions: pavements, roofs, facades, and softscapes [6]. Other studies that want to know the increase in wind speed use CFD computer simulations, such as research on the geometry of urban areas that form canyons and impact wind paths and increase wind speed [9][6].

A review of 25 studies on *Urban Cool Island* shows simulations that want to evaluate the parameters of solar radiation gain using ENVI MET while for wind speed using CFD simulations. Overall, the research process is through 2 stages. In detail, it can be seen in Table 2.

Table 2:Urban Cool Island research review

| No | | Author, year | Factor | Methodology | Parameter |
|---|---|---|---|---|---|
| 1 | Urban configuration | [8] | Urban configuration | Field measurement/ ENVI MET simulation | reduce the temperature in urban areas |
| 2 | | [11] | Urban Plan-Urban configuration | Field measurement/ GIS-ENVI MET simulation | reduce the temperature in urban areas |
| 3 | | [5] | Urban configuration | Field measurement/ GIS-ENVI MET simulation | reduce the temperature in urban areas |
| 4 | | [3] | Land use land cover-Urban configuration | Field measurement/ GIS simulation/ CFD | increase wind speed, reduce the temperature in urban areas |
| 5 | Urban Geometry | [7] | Urban Geometry | Field measurement/ GIS simulation/ CFD | increase wind speed, reduce the temperature in urban areas |
| 6 | | [12] | Urban Geometry | Field measurement/ GIS simulation/ CFD | increase wind speed, reduce the temperature in urban areas |
| 7 | | [13] | Urban Geometry | Field measurement/ GIS | increase wind speed, reduce the |

| No | | Author, year | Factor | Methodology | Parameter |
|---|---|---|---|---|---|
| | | | | simulation/ CFD | temperature in urban areas |
| 8 | | [15] | Urban Geometry | Field measurement/ CFD simulation | increase wind speed, reduce the temperature in urban areas |
| 9 | | [16] | Urban Geometry | Field measurement/ CFD simulation | increase wind speed, reduce the temperature in urban areas |
| 10 | Urban area materials | [20] | coatings, pavement materials, and roofs | Experimental measurements, GIS & ENVIMET | reduce solar radiation gain |
| 11 | | [21] | cold materials | Experimental measurements, GIS & ENVIMET | reduce solar radiation gain |
| 12 | | [17] | Roof | Experimental measurements, GIS & ENVIMET | reduce solar radiation gain |
| 13 | | [18] | Roof | Experimental measurements, GIS & ENVIMET | reduce solar radiation gain |
| 14 | | [19] | Pavement materials | Experimental measurements, GIS & ENVIMET | reduce solar radiation gain |
| 15 | | [22] | Facades | Experimental measurements, GIS & ENVIMET | reduce solar radiation gain |
| 16 | Materials Technology | [26] | Roofs and fractals | Pengukuran eksperimen, parametric | reduce solar radiation gain |
| 17 | | [10] | Green and blue space | Experimental measurements, GIS & ENVIMET | reduce solar radiation gain |
| 18 | Vegetation | [9] | Tree | Field measurement / Rayman | reduce solar radiation gain |
| 19 | | [19] | Park | Experimental measurements, GIS & ENVIMET | reduce the temperature in urban areas |
| 20 | | [23] | Park | Experimental measurements, GIS & ENVIMET | reduce the temperature in urban areas |
| 21 | | [28] | Park | Experimental measurements, GIS & ENVIMET | reduce the temperature in urban areas |
| 22 | | [24] | Park | Experimental measurements, GIS & ENVIMET | reduce the temperature in urban areas |
| 23 | | [25] | Park | Experimental measurements, GIS & ENVIMET | reduce the temperature in urban areas |
| 24 | | [29] | Park | Experimental measurements, GIS & ENVIMET | reduce the temperature in urban areas |
| 25 | | [30] | Park | Experimental measurements, GIS & ENVIMET | reduce the temperature in urban areas |

## 5. Potential Application of *Urban Cool Island* in Indonesia

As described above the *Urban Cool Island* research is urban-scale research. Computer simulation-assisted experimental research is an efficient and flexible way of modifying *Urban Cool Island*, rather than experimenting with field conditions. Research with this method is very possible for this research. The big challenge is to simplify complex real conditions in simple replicas. The next challenge is to design the research design and framework, this is an important key for the smooth running of the research. From the design of this research, hypotheses and variables have also been determined, then what computer simulation will be used. After that, the validation of the computer simulation is very important. This is to find out whether computer simulation can be used as an experimental tool.

For research timing, the time is divided into two stages: in the field and computer simulation time. Computer simulation takes time not only to modify experimental interventions but also to learn to master the simulation program. So from the start, it is necessary to design a careful research design. So during the computer simulation process, the time is not long due to the lack of mastery of the use of simulation.

At the research design stage, the largest portion of the proposed research budget is for computer simulation programs. The budget is used to pay for the simulation subscription license for a certain period of time, so [IS2] needs to be regulated [IS3] quite carefully, so that the research time is right with the program license time. So there is no need to extend the time to perform the simulation. It is also necessary to pay attention to the abilities and skills that must be possessed by researchers, namely the ability to interpret maps and the ability to operate computer simulations.

Table 4. The advantages, and disadvantages of Research *Urban Cool Island*

| Information | Advantages | Disadvantage |
|---|---|---|
| Research design | The right research design will be the key to the smooth process of experimental research. So the initial stages of theory need to be mastered properly. | The initial stage of designing a research design takes time, especially when making replicas of complex real conditions into simple replicas that meet the needs of the research. |
| Time | Research on the scale of urban areas: the time for experiments is more flexible and efficient | The biggest time is used during computer simulation. In the early stages before the validation simulation. Validation sometimes takes time to repeat and check back with field measurements. |
| Budget | Field research can be arranged in such a way that field research is cheaper | The largest investment in computer equipment, software purchases, and license subscriptions |
| Abilities/ skills | Ability to interpret maps and operate using computer simulations | If you do not master the ability to interpret and operate, you need help or hire someone else. And if you don't master the simulation process, it will take longer. |

## 1. Conclusion

Urban Cool Island research using experimental methodology assisted by computer simulations, is the right way to realize this research. Because of the scope of research on the scale of urban areas, it is very difficult to carry out experimental interventions in field conditions. By using computer simulations it will be more flexible and varied for variable intervention modifications. Before using computer simulation, the program must be validated before it can be used. The validation stage sometimes takes time to retest field conditions.

Research design is the key to conducting research, so it needs to be carefully designed from the start. This is to manage the budget, time, and preparation of the ability of researchers to operate computer simulations. In addition, it also requires the ability to make replica models from complex field conditions into models that suit research needs. The biggest investment budget for this research is to buy or subscribe to licensed software within a certain period, so the research design needs to be timed well so that the software subscription budget does not increase. The main advantage of this methodology is that the research results can be varied and able to test the hypotheses that have been determined at the beginning of the study.

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