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Innovative Design of Energy Efficient Residential Cooling System for Developing Countries

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Abstract. Energy conservation for buildings is a serious issue for any government and an efficient cooling system of a building in summer is one of major topics for conserving energy. In addition, the resources are very limited in developing countries of tropical regions. The principles and concepts have been discussed based on Systematic Innovation and it has been utilized in both analyzing and solving the problems. The paper is the extended summary and the revision of the previous research which deals with the innovative approach of enhancing the cooling temperature in the house by the unique problem solving method and the set of practical tools that could be applied for the value creation.

Keywords: Energy efficiency, natural cooling, green energy, systematic innovation, low-energy house.

1. Introduction

The whole world is in an endeavour to cope with the impact of climate change. Climate change, especially global heat is mainly caused by human activities such as massive use of natural resources like coal, oil and gas which are then discharged to the atmosphere resulting to an increase in the temperature of the earth. It is not easy to recognize the effects day by day because it takes a long time. People usually just becomes aware when the disasters happens. Climate change is the global issue that every country is affected. Hence, everyone concerned feels it is necessary to solve the problem. The energy conserving for buildings is serious issue even government [1-3] and efficient cooling system of a building in summer is one of major topics of energy efficient. In addition, the resources are very limited in developing countries. The paper deals with the practical approach of enhancing the cooling temperature in the house by the unique problem solving method. Systematic Innovation is a structured process and set of practical tools that can be used for the value creation. Because of global warming, the summer season especially in tropical region is now longer and higher in degree of temperature [4]. This makes the life of people more uncomfortable and people find many ways to reduce the heat to at least make them feel better. Air conditioners (AC) might be one of solutions but installation of air conditioners in buildings occur serious harmful side effects:

- The chlorofluorocarbon in AC is harmful to the ozone layer thereby causing global warming.
- An air conditioner consumes more power therefore more negative impact to the environment.
- An air conditioner also causes allergenic dangers to people if there is no timely maintenance.
- A poor people in developing countries does not have money to buy air conditioners neither to pay for electricity bills.

The initial analysis (the root cause analysis) is shown on Figure 1. The main reason of this problem is basically the negative impact to environment. The harmful effect of air conditioner is one of main factor of environmental friend house with the energy efficiencies. The unique approaches [5, 6] are applied to solve the issues.

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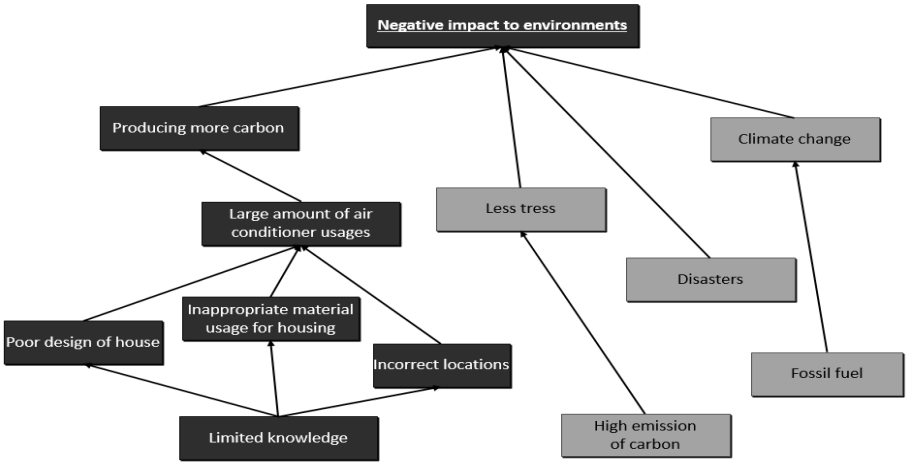

Fig. 1: Analysis of the Current Cause of Cooling System

The systematic innovation [6] is a structured process and set of practical tools could be applied to create products or services that deliver new value for the customers. It is also a set of continuous evolving tools that could improve ability to solve the problems. TRIZ [7, 8] is the most powerful methods for systematic innovation methodologies. The substance-field model [7-9] and 76 Inventive Standard [5, 10-13] were conceptualized by the founding father of TRIZ, Genrich Altshuller [1-3]. The Standard Solutions are grouped by constraints, so they can help the specialists find appropriate solution concepts [14]. But there are various reasons that the Inventive Standards are not applied widely [15]. Because of the reasons, the special notations so called Su-Field notations are introduced. The notations give intuitive explanations both problems and solutions based on the Inventive Standards. The core for Su-Field model notation is adopted by the queuing model notations also kwon as Kendall-Lee notations. Su-Field notations cover all of the Inventive Standards except for Group 5 which is guidelines for other four groups. Someone who does not even have the full knowledge of the 76 Inventive Standard solutions can understand the problems and candidate solutions intuitively based on Su-Field notations. This notation method is clarifying the Inventive Standards simpler ways and users can be guided to the candidate solutions from the problems based on Su-Field model with the minimal knowledge of 76 Inventive Standard solutions [15].

2. Problems of House Cooling System

The research is targeting to design the energy effective way of cooling inside of residences (or houses). The green solutions are always welcome and encouraged by the government and many international organizations who work for environment or climate change fields. Based on this problem, there are brief guidelines of solutions how to design a natural cooling system that:

- Help people install the auto cooling system that maximizes the use of natural resources and contribute to solve problem of climate change;
- Help people to enjoy the fresh, healthy air at a minimized cost;
- Apply poor friendly and eco-friendly technologies;
- Easy to install and maintenance.

To analyze the problem more clearly, Function Analysis and Root Cause Analysis (RCA) are applied. Based on the formulating the problem, the problem can be defined as follow:

Problems: **E**lement: Air (in the house); **N**ame of Feature: Temperature; **V**alue: Hot (>a)

The final goal is that the air in a house cool enough to stay without any additional resources included in an air conditioner. At the beginning, the problem is about cooling house but it actually about cooling air in the residence. The next step applies the problem into the function model (see the Figure 2).

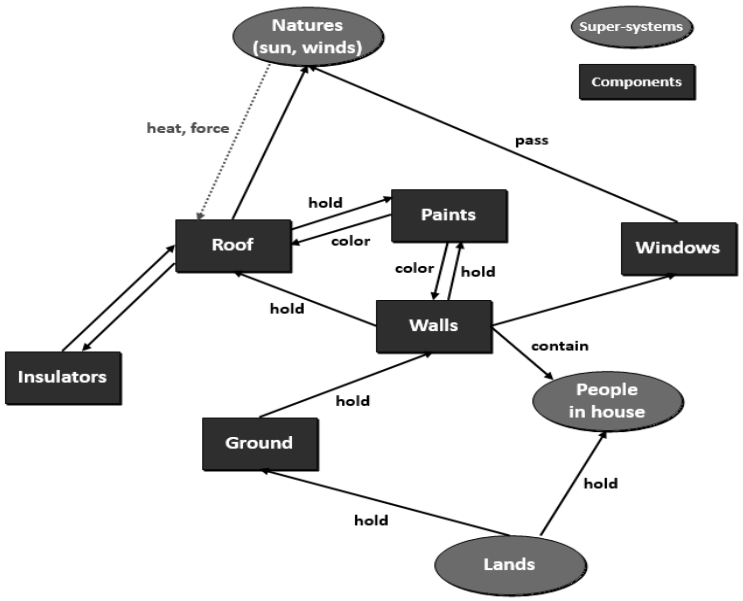

Fig. 2: Function Model of Cooling House

3. Concept Solution Design by Using Systematic Innovations

3.1. Enhanced Su-Field Model Summary

The innovative notation based on Su-Field model (Su-Field notation) is applied [15] and innovative notation schema is classified the Inventive Standards more simple way and users can be guided to the candidate solutions from the problems based on Su-Field model [5, 10, 11] with the minimal knowledge of 76 Inventive Standard solutions. Su-Field Notation is defined as follow:

$$(x/s/f):(/a)$$

where the symbols *x*, *s*, *f* and *a* stand for basic elements of the model as follows:

x = solution (or problem) types (*x* = 1, 2 or 4),
s = substance attributes,
f = field attributes,
a = strength of actions (*a*=0; *Normal* or *a*=1; *Stronger*)

The attributes of the substance *s* are as follow:

S^* = general terms of the substance that can solve the problems,
S^+ = +1 substance from basic structure to solve the problems,
S' = modify the substance (tool) to solve the problems without changing the number of components from basic structure,
S^- = -1 substance from basic structure (i.e., tool is missed),
S^∞ = substance (tool) is divided infinitely (Technical System Evolution),
S'' or S^2 = adding the clone of the substance (+1).

The attributes of the field *F* are similar with substance attributes:

F^* = general terms of the field that can solve the problems,
F^+ = +1 field from basic structure to solve the problems,

F' = modify the field to solve the problems without changing the number of components from basic structure,

F^- = -1 field from basic structure,

F^∞ = field is divided infinitely (Technical System Evolution),

F'' = adding the clone of the field (+1),

$\overleftarrow{F}$ = reverse direction of the field.

The attributes for fields and substances indicate how to modify the substances and the fields.

3.2. Problem Clarifications

The problem for removing of heating can be described as Su-Field Model. Object is the air inside of the house which directly affects the temperature of the house. Since the roof is directly acting the air in the house, the tool is the roof of house. Based on the Su-Field model, Problem Type-2 [15] is the problem that contains the harmful action and the candidate solution is basically removing the harmful function. The candidate solutions of Problem Type-2 could be determined as follow [15]:

$$2/S/F\{/0\} \rightarrow 2/S''/F$$

It means that one of substance (typically, Tool is first target to modify) is changed somehow to remove the harmful effect (i.e., heating air in the house).

4. Enhanced Cooling System for Residences

Changing the material and colours of the roof could be the solutions for removing harmful effect of the system. It could be observed that certain housing materials have higher absorption rate of heat and sunlight. It increases the overall temperature inside the house. Therefore, one of the recommendation is the roofs that polished copper (18% absorption) or white asbestos cement (42%). Thatched roof would make the house more airy. For the walls, white plaster (7%) or white marble (44%) would be better options than brick or concrete [2]. Roofs are the first contact of sunlight and dark-coloured roofs absorb more heat. As evidence to this, the infrared analysis below shows that black captures the most heat and sunlight. Opt for white (or light colours) instead which is about 20 degrees cooler compared to black. This reduces the overall cooling load of the house. Redesigning the shape of the roof is the alternative solution under the same concept solution (i.e., modify the roof). Ventilation techniques are helpful in letting the house breathe (see Figure 3). Hot air moves up by the stack effects and trapped air causes molds when moisture is created due to condensation. It must be ideally installed at opposite sides of the roof eaves to allow cross ventilation.

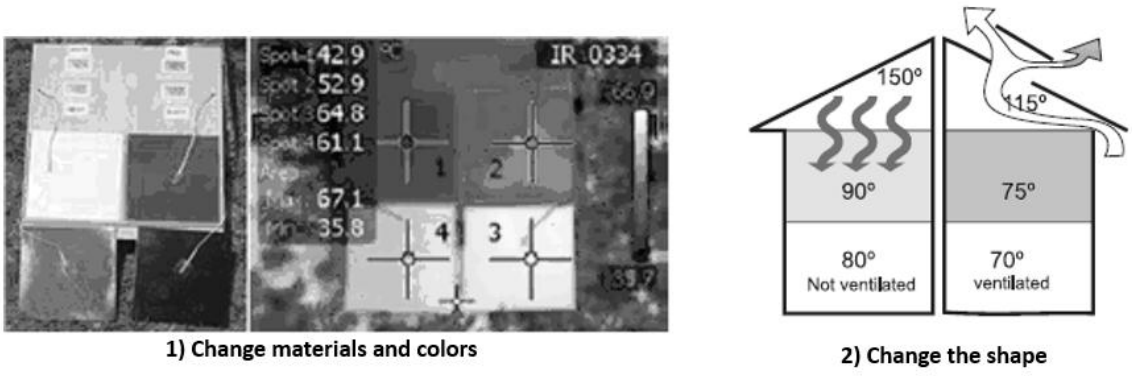

Fig. 3: Innovative Design of House for Cooling Enhancement [16]

5. Conclusions

The issues in this project are compromised without the use of sophisticated and expensive materials to improve and enhance the characteristic of certain equipment which has always been a part of our everyday lives. The major target of the project was developing the energy efficient way for cooling residences in developing countries. The new approach of Systematic Innovation method was applied for solving problems

for developing new design. Even though the research was dedicated with environment and civil industries, the pattern of Systematic Innovation approach could be also applied to other industries.

6. Acknowledgment

This paper is the revision and the extended summary of the existing research report [16] which has been based on the practical innovation class project in 2012. Special thanks to the students who had been hardly worked on the initial class project as the team during the practical innovation course.

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