# AC 2007-755: THE NEEDS PROBLEM MATRIX: PROVIDING SOME ORDER TO THE CHAOTIC IDEATION FUZZY FRONT END

**Madara Ogot, Pennsylvania State University**

Madara Ogot is an Associate Professor in Engineering Design and in Mechanical Engineering at Penn State. He is the co-author, along with Gul Okudan, of an introductory design text, Engineering Design: A Practical Guide. His current research interests include design under uncertainty, stochastic optimization and innovative design.

**Gül Okudan, Pennsylvania State University**

Gul E. Okudan is an Assistant Professor of Engineering Design at Penn State. She received her Ph.D. from University of Missouri-Rolla. Her research interests include intelligent shop floor control, manufacturing strategy modeling and measurement, solid modeling and measurement, product design and product design teams.

# The Needs-Problem Matrix: Providing Some Order to the Chaotic Ideation Fuzzy Front End


## Abstract

The fuzzy front end of the ideation process can often be chaotic, disorganized and seemingly haphazard, especially to student novice designers. Presented with a large array of pre-ideation tools and methods that are supposed to assist them in generating concepts that solve the correct problem, and take into account all aspects of the problem, students are often overwhelmed with information, or simply unable to see the connections or relevance of the data generated from the tools, students begin to view these pre-ideation design process steps as 'busy work'. The Needs-Problem Matrix (NPM) aims to tie seemingly disparate data from several pre-ideation tools together, presenting student designers with clear connections and a path forward in the ideation process. Use of the NPM ensures that relevant information is not omitted or ignored during concept generation. The NPM incorporates information garnered from patent analyses, black-box models, detailed customer needs analyses, and a design structure matrix used to establish design functional hierarchy. The NPM provides a flow of information from one tool to the next, clearly showing how they are all related, and illustrating what role each plays in the ideation process. Finally, the NPM also serves as a means to clearly document collected pre-ideation information and to aid in the decision making process.


## 1.0 Introduction

The fuzzy front end of the ideation process can often be chaotic, disorganized and seemingly haphazard, especially to student novice designers. Starting from introductory through capstone design courses, engineering students are presented with a large array of pre-ideation tools and methods that are supposed to assist them in generating concepts that solve the correct problem, and take into account all aspects of the problem (e.g. needs of the customer, pre-existing solutions, etc.). Although recommended pre-ideation tools and methods varies between design texts, common items include black-box modeling for problem decomposition; pairwise comparison charts or analytic hierarchy process (AHP) for attribute ranking or weighting, respectively; hierarchal lists or trees for organizing customer needs; and patent searches to find pre-existing solutions. Students are then supposed to organize and use the information generated as a framework for their concept generation.

Often overwhelmed with information, or simply unable to see the connections or relevance of the data generated from the tools, students begin to view these pre-ideation design process steps as 'busy work'. They simply go through the mechanics of using them – as they are often required to do so by the course instructor – but proceed with the concept generation step without using or referring to most of the gathered information.

The Needs-Problem Matrix (NPM), loosely based on the Quality Function Deployment's House of Quality,[7] aims to tie seemingly disparate data from several pre-ideation tools together, presenting student designers with clear connections and a path forward in the ideation process. Use of the NPM ensures that relevant information is not omitted or ignored during concept generation. With reference to Figure 1, the NPM incorporates information garnered from patent analyses, black-box models, detailed customer needs analyses with AHP weighting, and a design structure matrix used to establish design functional hierarchy.

The NPM provides a flow of information from one tool to the next, clearly showing how they are all related, and illustrating what role each plays in the ideation process. For example, it relates each of the problem functions to the identified customer needs. The former can then be weighted based on weights already calculated during the customer needs analysis, providing student designers with an indication of which functions within the design problem are most important to the customer. Finally, the NPM also serves as a means to clearly document collected pre-ideation information and to aid in the decision making process. The following sections discuss steps followed in generating the NPM. This is followed by an illustrative example from an actual student project.

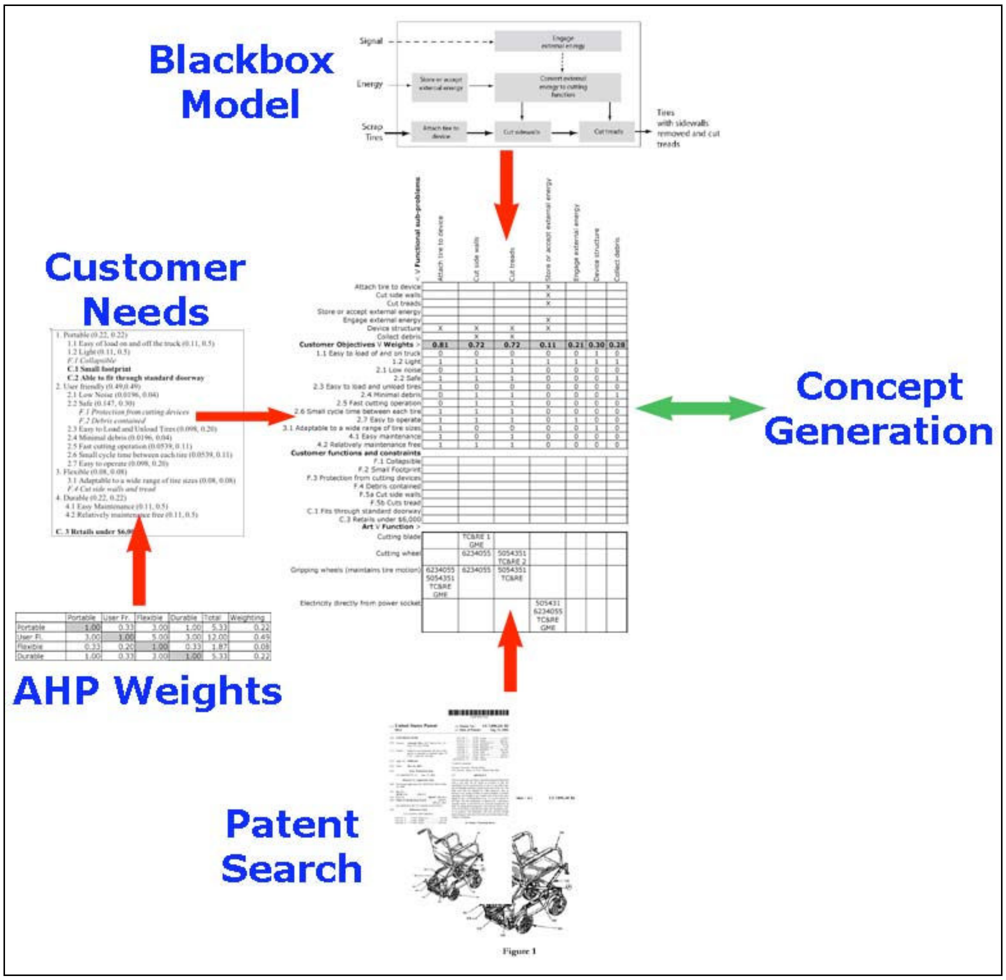



Figure 1. Schematic of how disparate information from several pre-ideation design tools and methods are integrated into the Needs-Function Matrix

## 2.0 Steps in Constructing an NPM

### 2.1 Customer Needs Analysis

Perform a customer needs analysis to find out what is important to the customer. The resulting hierarchal list should be weighted using methods such as the Analytic Hierarchy Process.[1] Data for gathering customer needs is usually done through customer interviews, focus groups, and if applicable, observation of the customer using an existing or competitor's product. The resulting list is then divided into three broad categories:[2]

1. Objectives or goals: Defines the attributes the design attempts to attain.
2. Constraints: Provides limitations or boundaries within which the final design specifications must lie.
3. Feature or functionality: Things that design must do. Typically binary, i.e., either the design has the functionality, or it does not.

The attributes are typically placed into hierarchies with the objectives and sub-objectives weighted based on what is important to the customer. An example of a hierarchal weighted (using AHP) objective list for a tire cutter is shown in Figure 2. The weights are represented by the two bracketed numbers after each of the attributes. The first number is the global weight of that particular attribute, i.e., its weight with respect to all attributes. The second number is a local weight determined with respect to the particular attributes level. For example for the level 1.x (i.e, 1.1, 1.2 and 1.3), the second number provides a weighting of the three attributes amongst themselves. Details on performing customer needs analysis can be found in Ogot and Kremer.[2] On completion of the customer needs analysis, the objectives, functions and constraints are located in the NPM as shown by step 1 in Figure 2.

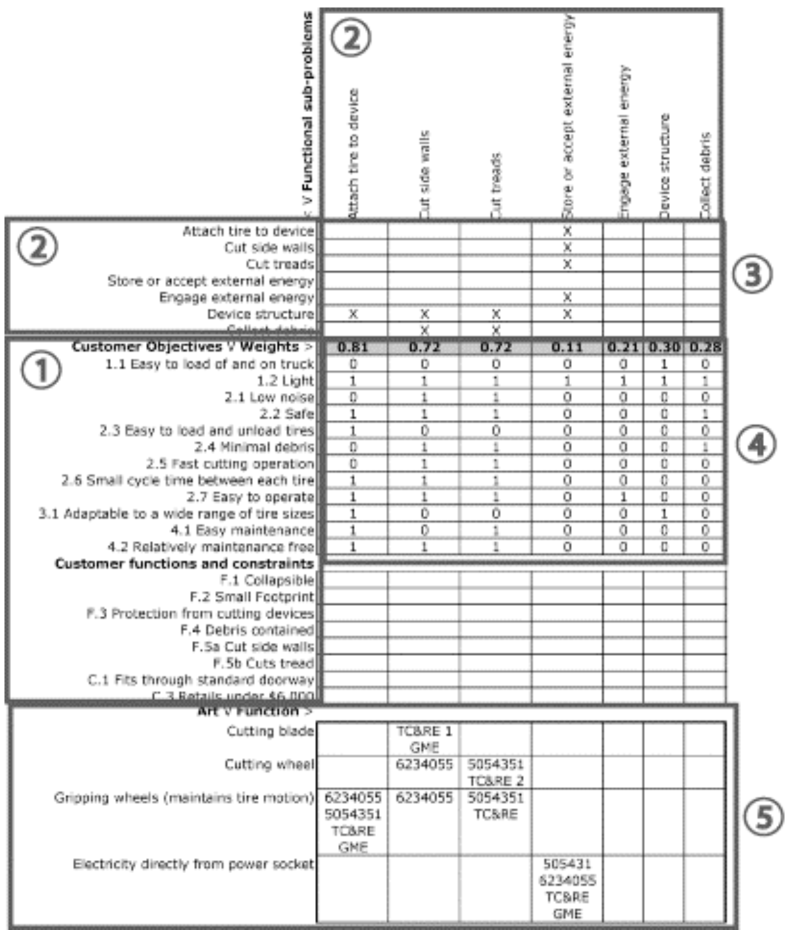
Table 1. Weighted hierarchal customer needs list

1. Portable (0.22, 0.22)
    - 1.1 Easy to load on and off truck (0.088, 0.4)
    - 1.2 Light (0.088, 0.4)
    - 1.3 Small footprint (0.044, 0.2)
    - *F.1 Collapsible*
    - **C.1 Small footprint**
    - **C.2 Able to fit through standard doorway**
2. User friendly (0.49, 0.49)
    - 2.1 Low noise (0.0196, 0.04)
    - 2.2 Safe (0.147, 0.30)
        - *F.2 Protection from cutting devices*
        - *F.3 Debris contained*
    - 2.3 Easy to load and unload tires (0.098, 0.20)
    - 2.4 Minimal debris (0.0196, 0.04)
    - 2.5 Fast cutting operations (0.0539, 0.11)
    - 2.6 Small Cycle time between each tire (0.0539, 0.11)
    - 2.7 Easy to operate (0.098, 0.20)
3. Flexible (0.08, 0.08)
    - 3.1 Adaptable to a wide range of tire sizes (0.08, 0.08)
    - *F.4 Cut side walls and tread*
4. Durable (0.22, 0.22)
    - 4.1 Easy maintenance (0.11, 0.5)
    - 4.2 Relatively maintenance free (0.11, 0.5)

**C.2 Retails under $6,000**

## 2.2 Problem Clarification

Problem clarification is readily facilitated using Black-box modeling.[3] An analysis of engineering systems reveals that they essentially channel or convert energy, material or signals to achieve a desired outcome. Energy is manifested in various forms including, optical, nuclear, mechanical, electrical, etc. Materials represent matter. Signals represent the physical form in which information is channeled. For example data stored on a hard drive (information) would be conveyed to the computer's processor via an electrical signal. An engineering system can therefore be initially modeled as a black-box (Figure 3) with energy, material and signal inputs and outputs from the system. In black box modeling, energy is represented by a thin line, material flows by a thick line, and signals by dotted lines as shown. The engineering system therefore provides the functional relationship between the inputs and the outputs.



| < V Functional sub-problems | Attach tire to device | Cut side walls | Cut treads | Store or accept external energy | Engage external energy | Device structure | Collect debris |
|---|---|---|---|---|---|---|---|
| Attach tire to device | | | | X | | | |
| Cut side walls | | | | X | | | |
| Cut treads | | | | X | | | |
| Store or accept external energy | | | | | | | |
| Engage external energy | | | | X | | | |
| Device structure | X | X | X | X | | | |
| Collect debris | | X | X | | | | |
| **Customer Objectives V Weights >** | **0.81** | **0.72** | **0.72** | **0.11** | **0.21** | **0.30** | **0.28** |
| 1.1 Easy to load of and on truck | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1.2 Light | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2.1 Low noise | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 2.2 Safe | 1 | 1 | 1 | 0 | 0 | 0 | 1 |
| 2.3 Easy to load and unload tires | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2.4 Minimal debris | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| 2.5 Fast cutting operation | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 2.6 Small cycle time between each tire | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 2.7 Easy to operate | 1 | 1 | 1 | 0 | 1 | 0 | 0 |
| 3.1 Adaptable to a wide range of tire sizes | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 4.1 Easy maintenance | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 4.2 Relatively maintenance free | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| **Customer functions and constraints** | | | | | | | |
| F.1 Collapsible | | | | | | | |
| F.2 Small Footprint | | | | | | | |
| F.3 Protection from cutting devices | | | | | | | |
| F.4 Debris contained | | | | | | | |
| F.5a Cut side walls | | | | | | | |
| F.5b Cuts tread | | | | | | | |
| C.1 Fits through standard doorway | | | | | | | |
| C.3 Retails under $6,000 | | | | | | | |
| **Art V Function >** | | | | | | | |
| Cutting blade | | TC&RE 1<br>GME | | | | | |
| Cutting wheel | | 6234055 | 5054351<br>TC&RE 2 | | | | |
| Gripping wheels (maintains tire motion) | 6234055<br>5054351<br>TC&RE<br>GME | 6234055 | 5054351<br>TC&RE | | | | |
| Electricity directly from power socket | | | | 505431<br>6234055<br>TC&RE<br>GME | | | |

Figure 2. Structure and steps in generating the NPM

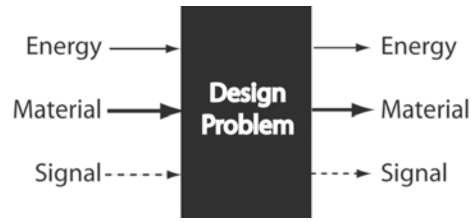


Figure 3. Energy, material and signal flows through a generic 'black box' design

Problem clarification involves forming a clear understanding of the problem. The overall problem represented by the black-box can be decomposed into *smaller sub-problems*. Problem decomposition allows solutions to complex engineering design problems to be found by considering simpler sub-problems. Design teams can then focus on the sub-problems critical to the success of the project first, deferring others. Note that the decompositions and the resulting black-box diagrams should be generic and do not commit the design team to any particular technological working principle.

Black-box modeling of existing systems that are to be redesigned, on the other hand, decomposes the existing system into sub-systems as opposed to sub-functions. For example, a computer hard drive is used to store and retrieve data. Within the hard drive, data is stored on a rotating magnetic disk, from which data is read using a read/write head. The head, situated at the end of a moveable actuator arm, can magnetize (write) or sense the magnetic field (read) on the disk. The head floats on the airflow generated by the disk rotation that maintains a very small gap between the two, preventing contact that may result in data loss. A black-box model of the hard drive in operation is shown in Figure 4. On completion of the problem decomposition, the identified sub-problems are placed as column *and* row headings as shown in Step 2 in Figure 2.

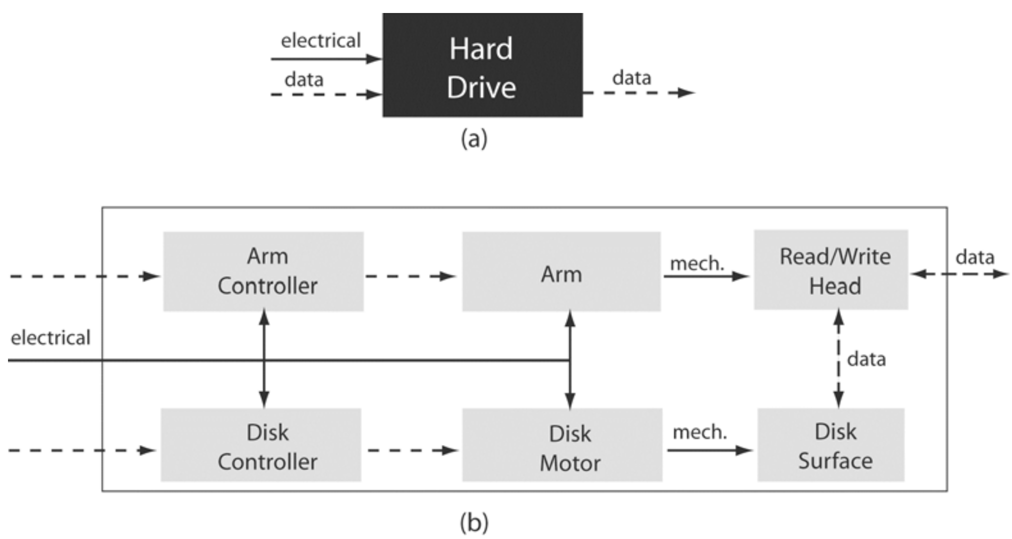


Figure 4. Black-box model of a computer hard drive

### 2.3 Sub-problem dependence

The dependence or independence between the sub-problems should be determined prior to ideation. Sub-problem dependence/independence indicates the order in which solutions to functional sub-problems must be considered. For example, for the problem, “to design a power-assisted bicycle.” Two possible sub-problems could be, *source of energy* and *convert energy to motion*. Concepts generated for the second sub-problem, will be dependent on concepts generated for the first, i.e., without knowing the options for sources of energy, one cannot think of ways to convert the energy into motion. In this example, the second sub-problem depends on the first. As the number of functional sub-problems increase, it becomes increasing important to have a firm grasp on these dependencies.

Function dependence/independence can be determined using a design structure matrix (DSM). The DSM readily identifies which sub-problems provide input to others and which sub-problems are independent and hence their solutions can be sought in parallel. A DSM is constructed by listing all sub-problems as row and column headings creating an *n* x *n* matrix, where *n* is the number of sub-problems. The latter are listed as close as possible to the solution order as best determined by the team. A generic design project DSM is shown in Figure 5. Note that the sub-problems may also be listed along the diagonals to make the matrix easier to read. Reading across rows, *Xs* indicate column sub-problems that provide direct input to corresponding row sub-problems. For example, reading across row *D* sub-problems *B* and *C* provide direct input to sub-problem *D* and are therefore marked with *Xs*. Likewise, reading down columns, *Xs* indicate row sub-problems that directly receive input from a particular column sub-problem. For example, reading down column *D* sub-problems *E* and *F* are marked. This means that *E* and *F* receive direct input from *D*.

Sub-problems *E* and *F* deserve a closer. Looking at row *E* shows that it requires input from both *D* and *F.* From row *F,* we see that *F* requires input from both *D* and *E.* The two sub-problems *E* and *F* appear to require input from and provide input to each other. Such sub-problems are said to be coupled or interdependent. Another way of looking at it is that neither sub-problem solution can be initiated nor completed without the other. One way of simplifying the handling of such sub-problems in DSMs could be to consider them as one task rather than two separate ones.Using the DSM structure created in Step 2 in Figure 2, the dependencies and be identified using X’s as shown in Step 3 in Figure 2.

| | A | B | C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **A** | **A** | | | | | | | | | | |
| **B** | X | **B** | | | | | | | | | |
| **C** | X | | **C** | | | | | | | | |
| **D** | | X | X | **D** | | | | | | | |
| **E** | | | | X | **E** | X | | | | | |
| **F** | | | | X | X | **F** | | | | | |
| **G** | | | | | X | X | **G** | | | | |
| **H** | | | | | X | X | | **H** | | | |
| **I** | | | | | | | | X | **I** | | |
| **J** | | | | | | | X | | X | **J** | |
| **K** | | | | | | | | | | X | **K** |

Figure 5. Design Structure Matrix

## 2.4 Needs-Functional Relationship

The determining the *needs-problem relationship* is similar to the *needs-technical requirements relationship* in the House of Quality (HOQ). Each of the enumerated customer needs is associated with the relevant functional sub-problem(s). Unlike the HOQ where the degree of the relationship (typically, none, weak, moderate and strong) is entered into the intersecting cells between the needs rows and the technical requirements columns, the NPM relationship, $\Phi$, is binary: the functional sub-problem does not contribute to the expressed customer need ($\Phi$=0) or it does ($\Phi$=1).

On completion, a column of zeros would alert the design team to a functional sub-problem over which the customer has not expressed a preference and thus presenting the team with two choices: (1) This may be an area that was overlooked and customer input should be sought, or (2) the lack of preference by the customer presents the opportunity to add "exciting quality" to their products. Exciting quality functions are those that may elicit the, "I did not know I needed it until I tried it', responses.[4] A row of zeros, on the other hand, indicates a customer need that the current problem formulation has overlooked. If this was not intentional (it may not be possible to meet all customer needs), the design team should revisit the problem decomposition process and ensure that the need is accounted for in at least one of the sub-problems.

Once the needs-problem relationships have all been determined, the relative importance of each sub-problem, $\gamma_i$, is calculated from

$$\gamma_i = \sum_{j=1}^{n} \Phi_{ij}\omega_j \tag{1}$$

where $\Phi_{ij}$ is the relationship between the $i^{th}$ functional sub-problem and the $j^{th}$ customer need, $n$ is the total number of customer needs, and $\omega_j$ is the relative importance of the $j^{th}$ customer need. The value of $\gamma_i$ informs the design team on which sub-problem contributes the most in meeting expressed customer needs and preferences. It is especially useful if design trade-offs need to be made between sub-problem solutions. Implementation of both the *needs-problem relationship* and the subsequent weighting of each of the sub-problems is shown as step 4 in Figure 2.

## 2.5 Patent Search

The patent search looks for existing solutions to the overall problem or any of the identified sub-problems. It reduces wasting resources by avoiding the implementation of existing solutions, thereby allowing the design team to focus its energies on areas where no solutions exist. Further it can provide inspiration for generation of new ideas. According to the World Intellectual Property Organization (WIPO), patents cover 90%-95% of worldwide research results. Making good use of patents through thorough searches and analyses could reduce 60% of research time and 40% of research costs. Further, searching patents helps companies avoid getting into legal problems by inadvertently infringing on other's intellectual property rights.[5]

The NPM captures key information from patent searches on prior art by creating an *art-function matrix* at its base. The rows represent the *art*, or the technological means by which a corresponding *sub-problem* (the columns) has been solved. At the intersection, a reference to the source of information (for example a patent number, or a product name) is entered for easy retrieval later on during ideation. The solution to the sub-problem does not necessarily have to come from the same industry or application.

### 3.0 Implementation: Student Example
### 3.1 Design Problem

Students in the Department of Mechanical Engineering's *ME340 Design Methodology*, a junior level class, were presented with the following design problem (condensed for the paper): In light of the world's increasing energy demand, developing nations are struggling to meet there respective needs. Remote villages are particularly affected. Wind power has great potential to address a variety of energy and environmental issues. Your team is to design, construct and test a sub-scale windmill to meet the needs of remote third world villages or households. Your design must meet the following specifications:

1. Low cost
2. Designed for easy mass production
3. The final materials must not be exotic (i.e., easily available in third world countries)
4. High efficiency
5. Scalable to meet the needs of a single household or small village
6. Low maintenance
7. Minimum of 20 year life cycle
8. Efficient operation in less than ideal wind conditions (i.e., variable wind speed from constantly changing directions)
9. Suitable for unattended operation
10. Simple assembly with minimal tools

To simulate a variable wind speed and direction scenario, your devices will be benchmarked using a set-up similar to that shown schematically in Figure 6. Two oscillating-head desk fans will be placed at $45^{o}$ to each other. All devices will be attached to the set-up using a common interface of two 1/4-20 bolts placed 6" apart as shown. Average power production from your wind-powered generator will be estimated using the motor-winch system shown in Figure 7. Once energized the provided motor will turn the winch and raise the mass, M (g), a height, H (cm), in a time, t (secs). The average power generated by your generator will therefore be calculated from Equation 2:

$$P = \frac{MGH}{t} \qquad (2)$$

where G is acceleration due to gravity.

### 3.2 Construction of NPM Prior to Ideation

The students were required to generate an NPM based on all the pre-ideation tools previously discussed before the begun the concept generation phase of the design process.

Presented below is a condensed write-up from one of the student groups for this portion of their project:[6]

In order to assess the needs of customers the group had to perform research in a number of different ways. An extensive patent search gave the group ideas of what has already been built or invented. The Internet was also a useful tool in researching various wind power generators as well as the problems they face. Finally, the assignment handed out to the group was evaluated to determine the needs of third world countries and to interpret these needs for our purposes. The Table 2 shows the needs of third world countries and the group's interpretation of these needs. The objectives were then weighted using the AHP process as shown in Table 3. Using the weights, the final weighted hierarchal customer needs list is shown in Table 4.

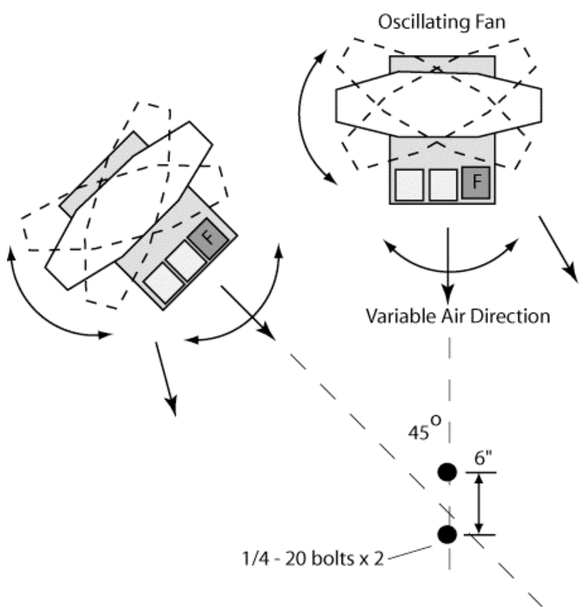



Figure 6: Schematic of Test Set-up

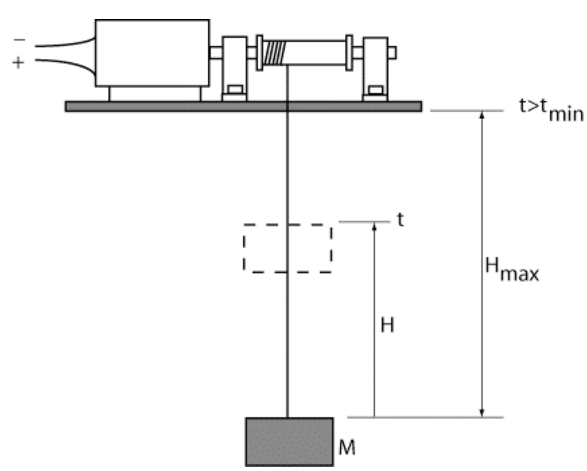



Figure 7: Rig to Measure Average Power

Table 2. Third World Customer Need Interpretation

| **Third World Needs for Wind Power** | **Interpreted Need** |
|---|---|
| Low cost | Must cost under $30 |
| Designed for easy mass production | Ease of production |
| The final materials must not be exotic | Available materials |
| High efficiency | Efficency |
| Scalable to meet the needs of a single household or small village | Scalable |
| Low maintenance | Ease of maintenance |
| Minimum of 20 year life cycle | Must last 20 years |
| Efficient operation in less than ideal wind conditions | Works in variable wind speeds |
| | Works in variable wind directions |
| Suitable for unattended operation | Self operating |
| Simple assembly with minimal tools | Ease of assembly |
| Assembly, operating and maintenance instructions communicated such that they can be understood in any written language or even to an illiterate operator | Simple illustrated instructions |

Table 3. AHP Weighted Hierarchal Customer Needs List

| | AHP | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ease of Production | Efficient | Ease of Maintenance | Variable Wind Speed | Variable Wind Direction | Ease of Assembly | Durability | Weight | Strength | Aesthetics | Total | Weighting |
| Ease of Production | 1 | 0.33 | 4 | 0.5 | 0.5 | 1 | 2 | 3 | 2 | 4 | 18.33 | 0.11 |
| Efficiency | 3 | 1 | 5 | 2 | 2 | 3 | 4 | 5 | 4 | 5 | 34 | 0.21 |
| Ease of Maintenance | 0.25 | 0.2 | 1 | 0.2 | 0.2 | 0.25 | 0.5 | 0.5 | 0.33 | 2 | 5.43 | 0.03 |
| Variable Wind Speed | 2 | 0.5 | 5 | 1 | 1 | 2 | 4 | 4 | 3 | 4 | 26.5 | 0.16 |
| Variable Wind Direction | 2 | 0.5 | 5 | 1 | 1 | 2 | 4 | 4 | 3 | 5 | 27.5 | 0.17 |
| Ease of Assembly | 1 | 0.33 | 4 | 0.5 | 0.5 | 1 | 3 | 3 | 2 | 4 | 19.33 | 0.12 |
| Durability | 0.5 | 0.25 | 2 | 0.25 | 0.25 | 0.33 | 1 | 1 | 0.5 | 3 | 9.08 | 0.06 |
| Weight | 0.33 | 0.25 | 2 | 0.25 | 0.25 | 0.33 | 1 | 1 | 0.5 | 2 | 7.91 | 0.05 |
| Strength | 0.5 | 0.25 | 3 | 0.33 | 0.33 | 0.5 | 2 | 2 | 1 | 3 | 12.91 | 0.08 |
| Aesthetics | 0.25 | 0.2 | 0.5 | 0.25 | 0.2 | 0.25 | 0.33 | 0.5 | 0.33 | 1 | 3.81 | 0.02 |

Next the black box model for the wind power generator was generated (refer to Figure 8). As can be seen below, the generator contains four main sub-problems, wind capturing device and conversion, mechanical advantage, alignment to account for changing wind direction, and generation of electricity.

Figure 9 presents the generated NPM. This was completed to determine what needs would be satisfied by each function, as well as what patents that were already around. The resulting NPM matrix is illustrated in Figure 9. Included therein are the patents found corresponding to each of the sub-problems along with the corresponding method of implementation (the art). The patents numbers are readily available for look up later in the project during concept generation.

## 4.0 Concluding Remarks

The paper has presented the rational behind and the construction of the Needs-Problem Matrix. The NPM helps students see the relationship between pre-ideation tools and how they can collectively be used in the ideation process. The NPM is simple to create and ensures that key elements of the pre-ideation process are not omitted or incomplete. Finally it allows design teams to organize the wealth of information they have generated.

Table 4. Weighted Hierarchal Customer Needs List

1. Efficiency (0.21)
    - 1.1 Maximum wind harnessing capability
    - 1.2 Minimum power loss from capture to motor
    - *F.1 Capture wind mechanically*
    - *F.2 Maximize mechanical power by means of mechanical advantage*
    - *F.3 Convert mechanical power to electrical power through generator*
    - **C.1 Must generate minimum required motor voltage**
2. Variable Wind Direction (0.17)
    - 2.1 Captures wind from varying directions
    - *F.4 Automatically align in direction of maximum wind velocity*
3. Variable Wind Speed (0.16)
    - 3.1 Works under changing wind speeds
4. Ease of Assembly (0.12)
    - 4.1 Assembled quickly and easily
    - 4.2 Has simple diagram assembly instructions
5. Ease of Production (0.11)
    - 5.1 Material is readily available
    - **C.2 Must be scalable**
6. Strength (0.08)
    - 6.1 Stands up to maximum wind speed
    - 6.2 Connection nodes withstand maximum use
7. Durability (0.06)
    - **C.3 Must last a minimum of 20 years**
8. Weight (0.05)
    - 8.1 Material is as lightweight as possible
9. Ease of Maintenance (0.03)
    - 9.1 Should require minimum maintenance during life cycle
10. Aesthetics (0.02)
    - 10.1 Should be attractive to third world villages and households

**C.4 Must cost under $30**

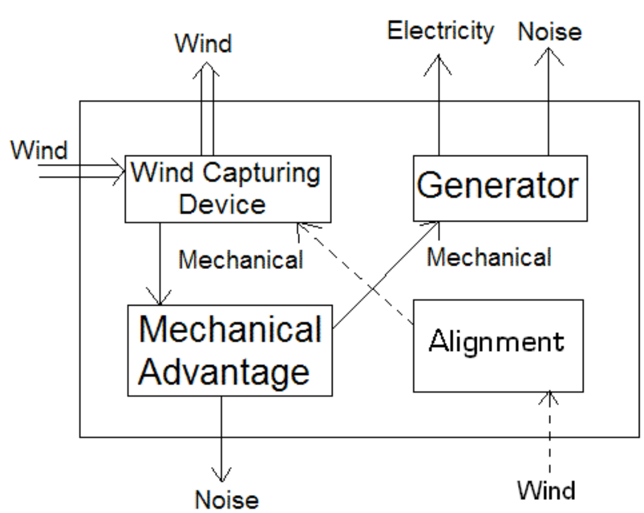



Figure 8. Black Box Diagram for the Wind Turbine

| Functional Sub-Problems | Capture Wind | Alignment | Mechanical Advantage | Generates Electricity |
|---|---|---|---|---|
| Capture Wind | | X | | |
| Alignment | | | | |
| Mechanical Advantage | X | X | | |
| Generates Electricity | X | X | X | |
| **Customer Objectives with Weights** | 0.43 | 0.29 | 0.11 | 0.17 |
| 1.1 Maximum wind harnessing capability | 1 | 1 | 1 | 1 |
| 1.2 Minimum power loss from capture to motor | 1 | 0 | 1 | 1 |
| 2.1 Captures wind from varying directions | 1 | 1 | 0 | 0 |
| 3.1 Works under changing wind speeds | 1 | 1 | 0 | 0 |
| 4.1 Assembled quickly and easily | 1 | 1 | 1 | 1 |
| 4.2 Has simple diagram assembly instructions | 1 | 1 | 1 | 0 |
| 5.1 Material is readily available | 1 | 1 | 1 | 1 |
| 6.1 Stands up to maximum wind speed | 1 | 1 | 0 | 0 |
| 6.2 Connection nodes withstand maximum use | 1 | 0 | 1 | 0 |
| 8.1 Material is as lightweight as possible | 1 | 1 | 1 | 1 |
| 9.1 Should require minimum maintenance during life cycle | 1 | 1 | 1 | 0 |
| 10.1 Should be attractive to third world villages and households | 1 | 1 | 1 | 1 |
| **Customer Functions and Constraints** | | | | |
| *F.1 Capture wind mechanically* | | | | |
| *F.2 Maximize mechanical power by means of mechanical advantage* | | | | |
| *F.3 Convert mechanical power to electrical power through generator* | | | | |
| *F.4 Automatically align in direction of maximum wind velocity* | | | | |
| **C.1 Must generate minimum required motor voltage** | | | | |
| **C.2 Must be scalable** | | | | |
| **C.3 Must last a minimum of 20 years** | | | | |
| **C.4 Must cost under $30** | | | | |
| Art vs. Function | | | | |
| Blades spin in the same direction of the wind direction | 2003/0025335 2004/0086373 6809432 | | | |
| Gear train | | | 2003/0025335 2004/0086373 2003/0156938 6809432 | |
| Propeller | 2003/0156938 | | | |
| Vane | | 6069409 | | |
| Blades shaped like cups | 6809432 | | | |
| Chain drive | | | 6069409 | |
| Funnel | 2003/0156938 | | | |
| Electric generator | | | | 6069409 6809432 2003/0156938 2004/0086373 2003/0025335 |

Figure 9. Needs Function Matrix for the Wind Power Generator

## References


1. Saaty,T.L., `Highlights and Critical Points in the Theory and Application of the Analytic Hierarchy Process', European Journal of Operational Research, Vol. 74, pp. 426-447, 1994.
2. Ogot, M. and G. Kremer, Engineering Design: A Practical Guide, Tafford Publishers, 2004.
3. Pahl, G. and Beitz, W., Engineering Design. A Systemaic Approach, 2nd Edition, London, Springer-Verlag, 1996.
4. Revelle, J.B., Moran, J.W., and Cox, C.A., The QFD Handbook, New York: John Wiley and Sons, Inc., 1998.
5. Idris, K., Intellectual Property - Powerful Tool for Economic Growth, Geneva: WIPO, 2003.
6. J. Meiser, J. Ritter and T. Young, 'Wind Power Generation Device', Final report for *ME 340 Design Methodology*, Penn State University, December 2006.
7. Ulrich, K. and Eppinger, S., Product Design and Development, 3rd Edition, New York: McGraw-Hill, 2003.