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# An Innovation for Hiking Backpack to Reduce Force and Load on the Back Part of Body with Hypothermia Early Prevention Function

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## Abstract

*Abstract*—Backpack is of the needs in carrying out many kinds of human daily activities. One of the activities is hiking. But, in carrying the backpack, we often have to carry luggage with heavy loads whereas the recommendation weight in carrying a backpack according to expert is 10% of the carrier body weight. Carrying a backpack with excessive load could lead to MSDs (Musculoskeletal Disorders). To solve this problem, researchers have created an innovative backpack called EMIRATES (Ergonomic Floating Bag To Reduce Force Using Suspended Load Technology). An ergonomic bag with a function to reduce impact force and load on the back when walking or running. This design is based on the voice of customer and following the current needs of mountain climbers. This research uses the Kano model which is used to determine customer satisfaction by specifying the attribute in designing and development process with the help of 36 respondents to decide the attribute. By using the Kano model, researchers could see the relationship between the desired performance criteria and customer satisfaction so that researchers could design the backpack with appropriate development. After the researcher got all the desired data then it will be divided into groups. These groups will be translated into a diagram so that the categories from each attribute could be seen. The plan to design EMIRATES bring out eight different types of attribute in designing hiking backpacks. The anthropometric approach is used to determine the dimensions that are used in the design of this backpack and to obtain an effective design for high performance and productivity. The design of EMIRATES is using the dimensions of back, shoulders, and arms so the anthropometric data that is used includes several body parts around the body segment. The main function of this bag is to reduce the force and load on the back part of the body using a suspension system that uses a sliding rail and pulley suspension system. Technically, the system is equipped with a shock breaker-like suspension that reduces impact. With this concept, it will be able to reduce the vertical load transfer. The vertical displacement of the load is also used to produce electric current by installing electromagnetic induction circuits which be used later as a body warmer. The features in this bag include an ambient temperature sensor, if the current temperature is below the setting point of the sensor, it will activate the body warmer automatically for hypothermia early prevention during the hiking process. With the variety of functions available, it is expected that this tool could facilitate backpack users and could minimize the risk of injury.

## Keywords

*Ergonomics Backpack, Hypothermia Early Prevention, Kano Model, MSDs, Suspension System*

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## 1. Introduction

Mountain climbing is an adventure activity in an open place that leads to a higher place, the mountain peak. This activity is becoming more and more favored by the nature lovers community by climbing to the high mountains in Indonesia. Activities that are full of adventures and challenges demand intelligence, skills, strength, and high power struggle.

In mountain climbing, there are lots of dangers and challenges that test one's ability and to be one with nature. One of the dangers and challenges in mountain climbing is being

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exposed to hypothermia due to the presence of cold air temperature at the top of a mountain. For example, at Mount Lawu, based on FreeMeteo's data, the air temperature at the peak during the day ranges from 10 ° C - 14 ° C while at night the average is 4 ° C - 0 ° C. Long exposure to cold can potentially cause hypothermia to mountain climbers. The following data shows the number of mountain climbers in Java who died due to hypothermia.

Hypothermia is a condition where the body faces difficulty regulating a balanced temperature due to cold air pressure. This condition is caused by the body's internal temperature decreasing to 35 ° C or even lower [1]. In fact, the human body can only regulate the temperature in the thermoneutral zone, which is between 36.5 to 37.5 ° C. Cold air pressure can cause the body's temperature regulating mechanism condition difficult to overcome cold. Hence the body will experience a drastic decrease in health conditions and body temperature from the normal body temperature.

The many dangers and challenges faced by mountain climbers must be addressed carefully so that this can be avoided. One of them being careful preparations regarding the equipment needed. One of the tools needed to climb a mountain is a backpack. The backpack is used by mountain climbers as a tool for carrying things and carrying them counts as a Manual Material Handling activity.

Carrying a backpack with heavy load and with a huge amount of equipment that needs to be carried can cause a variety of negative effects such as back pain, changes in posture and gait, and injuries [2]. Other impacts that occur will certainly make the activity more severe. Recommended weight of a backpack for teenagers and students is around 10% of body weight [3]. However, most mountain climbers carry bags over the recommended weight due to the many important equipment and supplies that needs to be carried.

Based on this, a backpack that can be used in the middle of the backpack is needed. In addition, there is a need for a bag that can contain body temperature and has features that can be used as body warmers to prevent increased hypothermia. With this, mountaineers can still carry the needed tools and equipment to reduce the risk of increased hypothermia. Therefore, the implementing team that has the ability to create innovations uses Suspended Load Technology with rails and pulley suspension systems to increase impact force and load on the back. Moreover, in order to support the temperature and warm the body by digital thermometers and integrated thermal insulation technologies.

## **2. Methodology**

### *2.1 Research Objects*

The object of this study is an hiking bag, a backpack that uses a suspension system to reduce back impact force and the early prevention of hypothermia. In addition to the suspension system, this backpack also has supporting features / attributes such as a bag that is comfortable to use, has the advantage of being able to be used as a warmer and able to detect temperatures.

### *2.2 Research Subjects*

The subjects in this study were hiking bag users in the UII campus area, with male and female sex in the productive age of 20 to 40 years, which are students and workers and love to climb mountains. The number of respondents needed is 36 respondents.

### *2.3 Research Procedure*

#### *2.3.1 Collect Voice of Customer*

The design of this product is based on the voice of customer and is supported by the conditions and needs of today's hikers. In determining the product, researchers

conducted a Focus Group Discussion activity on several respondents who had climbed and used hiking bags. Based on the FGD that had been done, complaints were found in the hiking bag, namely complaints of weight when carrying so much load and the absence of warmers in the bag to anticipate hypothermia. At this time there is no specific hiking bag that could help hikers to reduce the burden carried and as a body warmer. This makes researchers make mountain bag innovation products.

2.3.2 Kano Model

Kano Model is a model that is used to categorize attributes from products and even services based on how good can those products/services satisfy its customers [4]. Kano model classifies customer satisfaction towards the product attributes on how customers react and on their satisfaction. These classifications act as a new design decision. Kano model is used in activities such as identifying customer’s needs, determining functional necessity, concept development, and competitive product analysis.

Questionnaire is made with contradictory questions, namely how does the consumer react if a feature is made (positive) and if a feature isn’t made (negative). The level of importance or satisfactory for each question is the same, which is 1 (one) for really like, 2 (two) for like, 3 (three) for neutral, 4 (four) for dislike, and 5 (five) for really dislike. In the evaluation stage, the questionnaire results are imported into a Kano evaluation table. Positive questions are included in functional table, meanwhile negative questions are included in dysfunctional table. Table I shows an example of a Kano evaluation table.

TABLE I  
KANO EVALUATION

CUSTOMER REQUIREMENT → ↓		DYSFUNCTIONAL (Negative) QUESTION				
		1. Like	2. Must-be	3. Neutral	4. Live with	5. Dislike
FUNCTIONAL (Positif) QUESTION	1. Like	Q	A	A	A	O
	2. Must-be	R	I	I	I	M
	3. Neutral	R	I	I	I	M
	4. Live with	R	I	I	I	M
	5. Dislike	R	R	R	R	Q

After that, the results of data processing are analyzed by placing each attribute of the questionnaire. There are 5 (five) types of product attributes that have a relationship with customer satisfaction, namely Must-Be, Attractive, Indifferent, One Dimensional, and Reserve [5]. The result of these placements can be observed with the Fig.1 below.

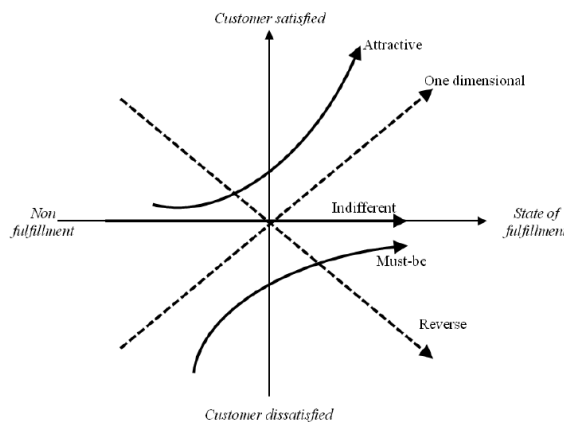


Fig. 1. Kano Diagram

Placed attributes will be included inside a quadrant in the graph as seen in figure 2. By finding the average of respondent’s answers as follows.

$$\text{Extend of Satisfaction} = \frac{A+O}{A+O+M+I} \quad (1)$$

$$\text{Extend of Dissatisfaction} = \frac{O+M}{(A+O+M+I)(-1)} \quad (2)$$

Based on the averages, an attribute that follows customer's satisfaction and dissatisfaction can be found. Positive attributes will be continued while the negative attributes will be corrected [6].

### 3. Result and Discussion

#### 3.1 Kano Model

This study uses Kano Model which is useful for determining customer satisfaction by determining attributes in the design and development of backpack designs with 36 respondents in the determination and criteria for attributes. By using Kano model, researchers can see the relationship between desired performance criteria and customer satisfaction so that researchers can design backpacks with appropriate development.

After the researcher gets all the desired data, the researcher will group each question into aspects that exist, after that the results of the data will be translated into a diagram so that the categories of each attribute can be seen.

The EMIRATES design planning that is done resulting 8 types of attributes in in the hiker backpack designing process. The attributes used for the questionnaire are stated in Table II.

TABLE II  
8 ATTRIBUTES BACKPACK  
**PRODUCT REQUIREMENT**

<b>A1</b>	Easy to use bag
<b>A2</b>	Bags that can be used as warmers
<b>A3</b>	Bags that can detect temperature
<b>A4</b>	Bags that remain light when carrying items
<b>A5</b>	Comfortable bag to use
<b>A6</b>	Bags that are made from strong
<b>A7</b>	Bags that can be used by many ages
<b>A8</b>	Bags that can glow in dark places

To identify the level of importance of consumer preferences into the Kano category, the questionnaire was compiled using functional and dysfunctional statements. Respondents were asked to provide preference categories for each attribute based on the questions given, namely attractive (A), indifferent (I), one directional (O), must be (M), questionable (Q), and reverse (R). The results of tabulating the evaluation of consumer preferences and classification of the categories are in Table III.

TABLE III  
TABULATION OF EVALUATING CONSUMER PREFERENCES

Kode Atribut	Product Requirement	A	O	M	I	Total	Category	DISSAT IS.	SATISF AC.
								O+M	A+O
								A+O+M+I	A+O+M+I
A1	Easy to use bag	8	7	16	5	36	M	0,639	0,417
A2	Bags that can be used as warmers	20	5	4	7	36	A	0,250	0,694
A3	Bags that can detect temperature	17	4	5	10	36	A	0,250	0,583
A4	Bags that remain light when carrying items	16	1	15	4	36	A	0,444	0,472
A5	Comfortable bag to use	8	11	8	10	36	O	0,528	0,528
A6	Bags that are made from strong	6	3	18	9	36	M	0,583	0,250
A7	Bags that can be used by many ages	16	3	6	11	36	A	0,250	0,528
A8	Bags that can glow in dark places	5	0	6	25	36	I	0,167	0,139

Based on the tabulation of evaluation of consumer preferences, the next step is attribute placement based on the assessment of dissatisfaction index and satisfaction index to determine the position of attributes appropriately. This can be seen in the following scatter graph image.

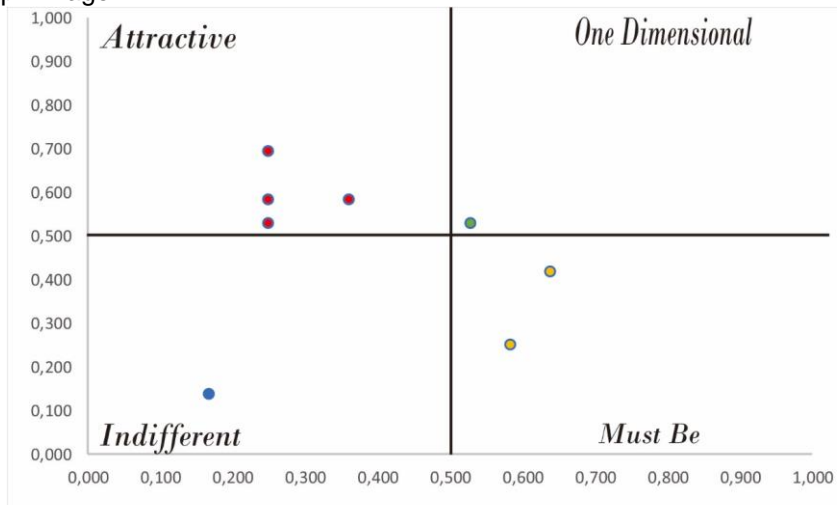


Fig. 2. Scatter Diagram

The EMIRATES design planning is based on the criteria on Kano Model by developing designs according to the needs and desires of consumers by meeting the criteria, namely:

1. Must be

In this criterion, all attributes must be fulfilled because these criteria are absolute which affect customer satisfaction where if not fulfilled it will reduce satisfaction. There are three attributes that belong to this category, which are easy to use and strong. Backpacks are designed with a concise and powerful function so that they can meet all the criteria in the must be category.

## 2. One Dimensional

In this criterion all attributes will increase customer satisfaction if attributes can be applied. There is one attribute that belongs to this category, which is comfortable to use.

## 3. Attractive

In this criterion the attributes applied are four attributes which belong to this category, namely backpack which can detect temperature and use.

## 4. Indifferent

In this category there are four attributes, namely bags that have a combination of colors, attractive bag shapes, there are many pockets and have specifications.

### 3.2 Recommended Weight of Backpack

Backpacks are a part of daily life, one of them is for mountaineers. Using an inappropriate backpack has a significant negative impact on backpack users. The International Pediatric Association (ICPA) Chiropractor and the American Occupational Therapy Association (AOTA) emphasize that the weight of a backpack should not be greater than the recommended weight for children, teenagers and students, which is 10% of body weight. American Occupational Therapy Association recommends that the luggage weight should not exceed 10% of total body weight. Excessive backpack weight causes musculoskeletal injury and spinal abnormalities (Scoliosis, Kyphosis and Lordosis) in the user.

Musculoskeletal injury or disorder is a condition that interferes with the function of joints, ligaments, muscles, nerves and tendons, and the spine. Musculoskeletal disorders are degenerative diseases, diseases that can slowly damage body tissue. This will lead to pain and reduce one's ability in motion activities.

Musculoskeletal can be caused by using strength to carry out activities such as lifting or carrying heavy objects repeatedly using the same muscle or joint group. So that various studies have concluded that the weight of school backpacks should not exceed 10% of body weight

### 3.3 Product Design



**Fig. 3.** Product Design



**Fig. 4.** Engineering drawings

### 3.4 Innovation Aspect

EMIRATES is designed with the aim of reducing the risk of MSDs (Musculoskeletal Disorders) caused by the use of bags that do not match the recommended load with the designs that have an ergonomic aspects or comfortable to the user. With that, the EMIRATES bag is equipped with a suspension system to reduce the bag burden felt by climbers. In addition, EMIRATES is also equipped with warning features and early handling of hypothermia by combining the LM35 connector and thermoelectric technology which are both integrated. If the temperature of the environment is already at the limit of the desired temperature of the user, then the warning indicator will automatically turn on so that the body warmers that are on the back will also be activated automatically.

### 3.5 Anthropometry

Anthropometry can be expressed as a study relating to the measurement of the dimensions of the human body [7]. Anthropometry data is very useful for achieving effective design for high performance and productivity [8]. To create the design of EMIRATES, the body dimensions of the back, shoulders and arms are used, so that the anthropometric data used includes several body parts that are around the body segment. Using a 50 percent presentation, it is hoped that this tool can be used by people in general.

Anthropometric data that is used were taken from Indonesian Anthropometry Data, taken from research data of several journals in the last 4 years, namely from 2014-2018 with indicators of all tribes; Ages 17 to 36 years; all sexes. The dimensions used can be seen in the table below:

TABLE IV  
ANTHROPOMETRIC RESULT

No.	Anthro Dimension	Product Dimensions	Calculation			Calculation Results (cm)
			Percentile	Percentile Value (cm)	Allow	
1.	Shoulder height in a sitting position	Bag Length	P <sub>50</sub>	59,05	0,95	59

2.	Shoulder width	Bag Width	P <sub>50</sub>	40,03	0,95	40
3.	Length of upper arm	The length back of the bag	P <sub>50</sub>	35,32	095	35

### 3.6 Usability

Usability comes from the word "can be used" which means it can be used correctly. Besides that, the characteristics of the usefulness of EMIRATES based on the concept of ISO 9241. Usability can also be defined to how long a product can be used by certain users to achieve certain goals with effectiveness, efficiency and satisfaction in the context of the specified usage. One way that can be used to determine the level of user satisfaction with existing products and to get feedback for improvement of procedures is by interviewing the user directly. The attributes considered for analyzing EMIRATES functionality are effectiveness, satisfaction, and comfort.

EMIRATES has a suspension on the back of the bag so that it can reduce the burden felt by users in carrying out climbing activities so that it can reduce the possibility of users being exposed to CTDs (Cummulative Trauma Disorders) on the back. In addition, on the back side there is also a body heating device that is used as one way to prevent Hypothermia. This body warmer has its own temperature control device on the left side of the sling, with the aim of this the body warmer can be activated automatically at the temperature capacity specified by the user. To facilitate the vision of other climbers when climbing with groups, this bag has material that is glow in the dark, making it easier for climbing in conditions that are less illuminated or at night, thereby reducing the possibility of members scattered or lost because of losing track.

## 5. Conclusion

EMIRATES is an ergonomic bag that uses a pulley suspension system which causes vertical displacement of the load so that it can reduce the burden when carrying a backpack. EMIRATES is also equipped with a reminder feature so if the ambient temperature is below the setting point after the body warming sensor will be activated for the early treatment of hypothermia during climbing. EMIRATES are expected with the advantages and features it has to be a solution to the problems that have been experienced by climbers and users with activities that require carrying heavy loads on a backpack that can prevent the risk of injury safely and comfortably.



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