

Integration of Function Analysis and Trimming Method: A Systematic Approach for Improving a Spinal Board Design

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Abstract— Function analysis primarily distinguishes components in a system and explains the function interactions amongst the components' pairs. It assists designers in revealing the main problematic areas (components) and contradictions. The trimming method assists in generating a simple design; thus, it can reduce costs and the number of faults. This study integrated the function analysis and trimming method as a systematic approach to product concept design based on the problem-oriented concept. A spinal board is an evacuation device for patients with an injured spinal cord. A case study of improving a spinal board design is conducted to demonstrate the applicability of the proposed approach. The study resulted in an alternate design of spinal board with some inventions which deliver improved performance in decreasing injury, increasing comfort and safety, and satisfying the users' requirements.

Keywords: Function analysis, Trimming method, Spinal board, Ergonomics

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1. Introduction

Spinal Board is a commonly used tool in the Emergency Medical Services (EMS) procedure by medical workers and volunteers to evacuate patients with a suspected spinal injury on the field. Several publications initiated the generally established paradigm that patients vulnerable to spinal injury should be immobilized on a spinal board to avoid injury deterioration [1]. This tool can stabilize the patients' spine and restrict the patients' mobility [2]. Indonesia is one of the most disaster-prone countries in the world. The country faces multiple hazards such as earthquakes, tsunamis, volcanic eruptions, flood, landslides, drought, and forest fire [3]. Therefore, Indonesia must have a good standard of care for the impact of natural disasters and traffic accidents. One of the common injuries as a result of disasters and traffic accidents is spinal cord injury. In Indonesia, the rigid long spinal board is found in every emergency ambulance and is the primary piece of equipment used to extract, carry and support the patient, resulting in long-term disability, often with profound effects with spinal injury en route to the hospital.

Figure 1 shows the existing spinal board commonly used in Indonesia. Nevertheless, some studies have found the adverse effects of using a rigid spinal board, including breathing problems [4][5], increased intracranial pressure in patients with brain injury [6], pain affected by lying on the spinal board [7][8], and the increase of pressure ulcers [9][10][11] investigated the effects of standard spinal immobilization on a group of healthy volunteers about convinced pain and discomfort. All participants developed pain within the direct observation period. Kwan and Bunn [12] investigated the effects of spinal board use on healthy users. The results showed that the use of a spinal board and the enhancements provided a substantial decrease in spinal movement. However, it significantly increased respiratory effort, skin ischemia, pain, and discomfort. A most recent study by Corbacioglu et al. [13]

also proved that using a spinal board could significantly increase visual analog scores (VAS) and decrease systolic blood pressure.

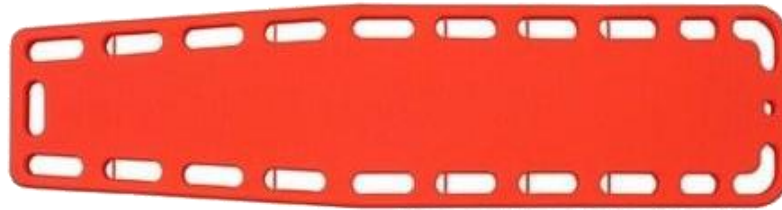


Figure 1. Commonly Used Spinal Board in Indonesia [14]

Since it has been found the advantages and disadvantages of spinal immobilization, there was a need to develop and test an alternative design of a spinal board used as a rescue device with fewer disadvantages when used during conveyance. Zadry et al. [15] have identified the design requirements for the ergonomic spinal board using quality function deployment (QFD). Those requirements were then implemented into an alternative design of an ergonomic spinal board [16]. The design produced a lighter board to carry and could be folded to minimize storage space. However, based on prototype evaluation, there were still shortcomings in the design. One of them is that the users still feel uncomfortable during use because of the absence of a thin and soft layer on the board's surface. Thus, a subsequent study [17] was conducted to develop the design requirements of the spinal board, which can maximize meeting the user needs. The study implemented an integrated method to determine ergonomic product design requirements, then used those requirements as a reference to design a more ergonomic spinal board which accordance with user needs.

This study continues the previous studies by improving the spinal board design to generate a more ergonomic design to improve patient comfort, provide the least adverse effects, and provide an effective and efficient immobilization process. The study integrates function analysis and trimming methods in designing the product. The integrated method offers a systematic approach to product concept design based on the problem-oriented concept, which can provide an effective process in product development [18].

2. Method

A redesign is essential to the product development process (Smith et al., 2012). The new redesign methodology consists of ten steps: choose the target product, identify needs, choose reference products, identify components, build a component factor table, determine component factor weights, extract key components, identify conflicts, apply design principles, and verify results [19]. In redesigning the spinal board, eight of the ten steps have been done in the previous studies by Zadry et al. [15][16][20]. This study continues the redesign process on the ninth step, applying design principles using the integration of function analysis and trimming method.

2.1 Function Analysis

Function analysis primarily distinguishes components in a system and explains the function interactions amongst the components' pairs. Ko and Kuo [18] proposed three stages of function analysis, including component analysis, interaction analysis, and function modeling. The component analysis is meant to identify an engineering system component and its appropriate super system (Engineering system and its environments). Then, it is developed an algorithm for creating an interaction matrix by the following steps: (1) Enter the components in the interaction matrix in similar order in a row and a column; (2) Mark a positive (+) sign in all cells where components in the row and column interrelate and mark a negative (-) sign in all other cells; (3) Check for the diagonal symmetry of the interaction matrix; (4) Check the interaction matrix and eliminate components with no interactions.

The next stage is components identification for function analysis modeling, which is derived by

classifying the components into (1) Primary function - the function(s) where the system is designed for; (2) Objects - receiver component of an action/function; (3) Target/product - object of the system's primary function; (4) Main tools - the tool which offers a primary function for the target; (5) Auxiliary tools - all other system components which accomplish some supporting functions; (6) Environmental element - the environment or nearby systems.

2.2 Trimming Method

Trimming method assists in generating a simple design. It eliminates unnecessary or replaceable components. Thus, it can reduce costs and the number of faults. However, it can increase general functionality. The trimming method recommends the following rules [18]: (1) Rule A: Function carrier can be trimmed if the authors eliminate the object of its valuable function; (2) Rule B: Function carrier can be trimmed if the object of function performs the valuable function itself; (3) Rule C: Function carrier can be trimmed if another component performs its proper function; (4) Rule D: Function carrier can be trimmed if a new or niche market can be identified for the trimmed product; (5) Rule E: Function carrier can be trimmed if the function can be performed the same or better by a new or an alternative part providing enhanced performance or other benefits (such as low cost).

The steps of the trimming process are as follows [18]: (1) Implement FA. FA can help us ascertain positions for trimming; (2) Define Trimming Priority. The trimming process can be highlighted by determining a new carrier; (3) Establish Trimming Plan. The trimming Plan arranges the thought process of trimming. The trimming method delivers an approach to assigning functions to a new carrier and provides a solution. It also proposes various alternatives for removing similar components. These alternatives signify a variety of potential inventions.

3. Result and Discussion

3.1 Function Analysis

The object is the patients who belong to the super system. The board directly interacts with the handle, while the hook connects the strap with the board. However, the strap does not have a direct relationship with the board. The types of interaction between the components in the spinal board system were then identified. The symbol "+" specifies that there are relationships between two components, while the symbol "-" specifies that there is no relationship between two components. Table 1 shows the interaction analysis results for the spinal board.

Table 1. Interaction Analysis of the Spinal Board

From-To	Board	Handle	Hook	Strap
Board		+	+	-
Handle	+		+	-
Hook	+	-		+
Strap	-	-	+	

3.2 Function Modelling in Graphics

The function model of the spinal board was then constructed based on the interaction analysis results, as shown in Figure 2. The function model was developed in graphics and became the preliminary function model of the spinal board.

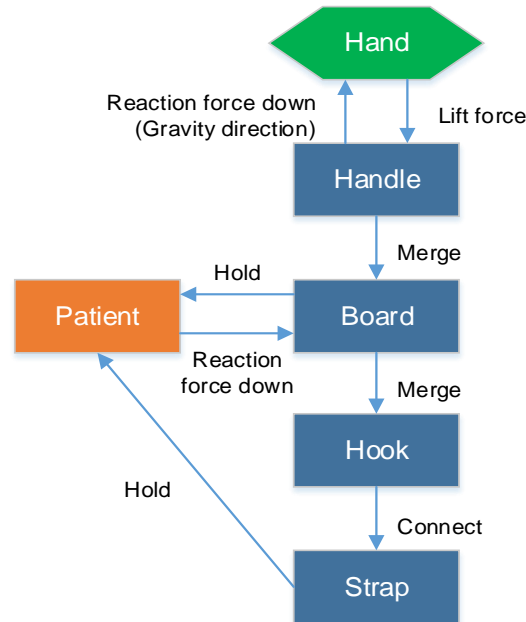


Figure 2. Preliminary Function Analysis of Spinal Board

3.3 Function Improvement

Function improvement was made on the current spinal board to produce a new product design that meets the user's requirements. The improvement refers to the design requirements which were obtained from the previous study [21]. Based on those results, some new functions of the spinal board are improved, including protecting the spine, restricting the head and neck, and placed vertically. Thus, new mechanical components or mechanisms were created to realize the above functions. These new components were combined with the initial spinal board. The function improvement of the spinal board is shown in Figure 3. The components and mechanisms consist of: (1) Side buffer with 900 rounds; (2) Vertical buffer; (3) EVA foam with 4 mm thickness; (4) Foam layer with 4 mm thickness and polyethylene; (5) EVA foam with 20 mm thickness for protecting the spine; (6) EVA foam with 15 mm thickness for neck restraint; (7) EVA foam with 4 mm thickness for head restraint.

3.4 Trimming Application

The trimming method was then applied to the developed model, aiming to get a more advanced but simple design without ignoring the users' desires for the product. Rule C (Function carrier can be trimmed if another component performs its proper function) was firstly adopted by eliminating the function carrier because other functions can replace it. As the strap connection, the function carrier on the hook component can be shifted to the handle on the board. Furthermore, rule D (Function carrier can be trimmed if a new or niche market can be identified for the trimmed product) was adopted for the first component. The final function model of the spinal board after trimming can be seen in Figure 4. There is a new component in the form of a handle that can be rotated on the component which previously served as the spinal board handle. The replacement of the fixed side cushion was proposed because it cannot restrain the victim optimally and increase the load borne by a shaft which can cause damage to the spinal board.

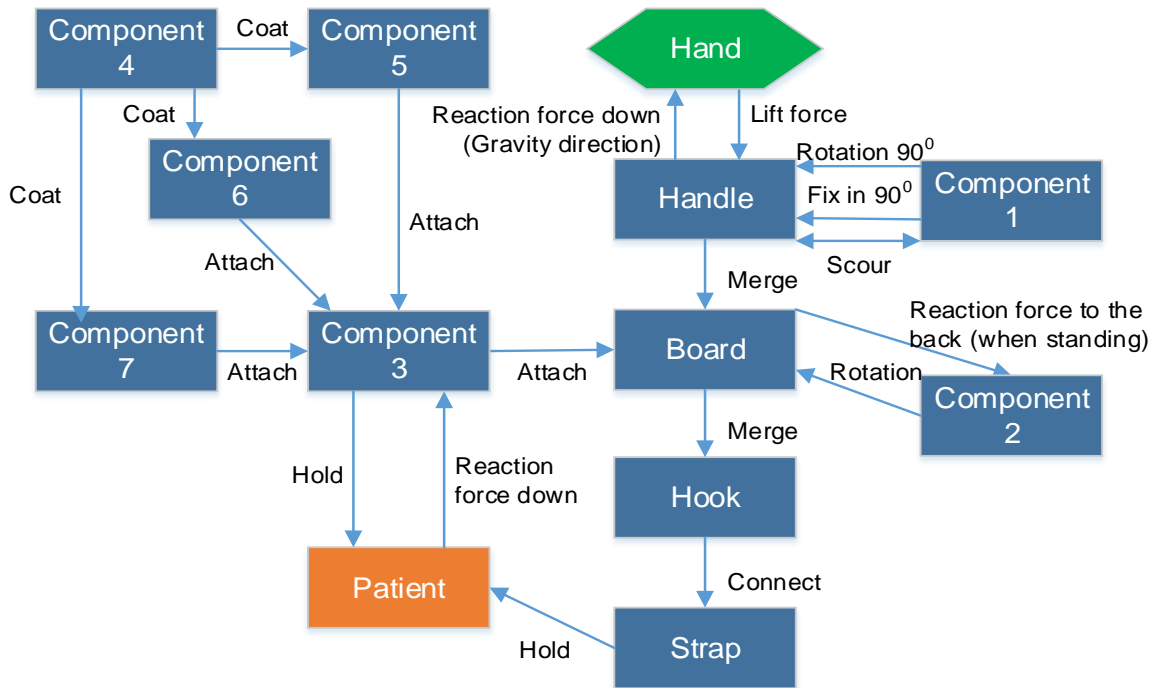


Figure 3. Function Analysis Improvement of Spinal Board

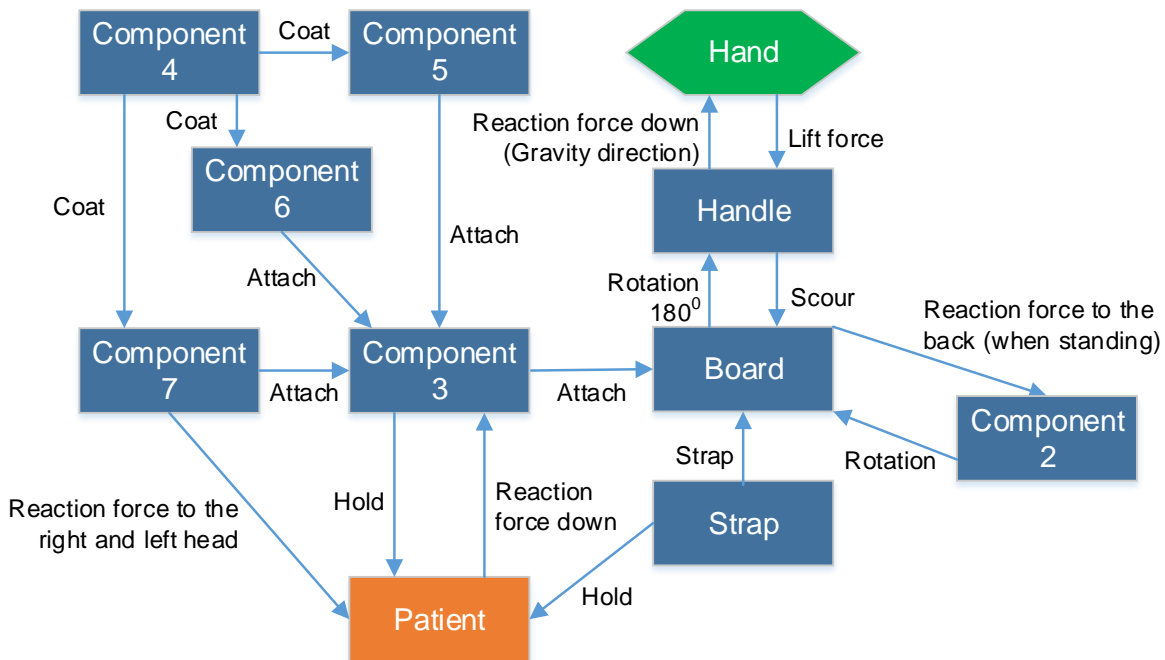


Figure 4. Final Function Model of Spinal Board after Trimming

3.5 Alternative Design of Spinal Board

The final trimming function model of the spinal board was used to design a spinal board that accommodates users' expectations and needs in terms of ergonomics and product quality. The new design of the spinal board includes the additional feature of a head immobilizer which can be released when not needed. The head immobilizer is fitted with foam to make it more comfortable. The material

used for the main board, the side buffer (handle), and the vertical buffer is fiberglass combined with Epoxy. The board is covered by EVA foam with a 5 mm thickness coated with Taslan fabric.

Furthermore, the head immobilizer is covered by EVA foam with a 10 cm thickness coated with Taslan fabric. Another feature is the vertical buffer, which positions the product in a vertical state. The buffer is positioned at the back of the board. Figure 5 shows the spinal board with the head immobilizer and the spinal board in a standing position with a vertical buffer.

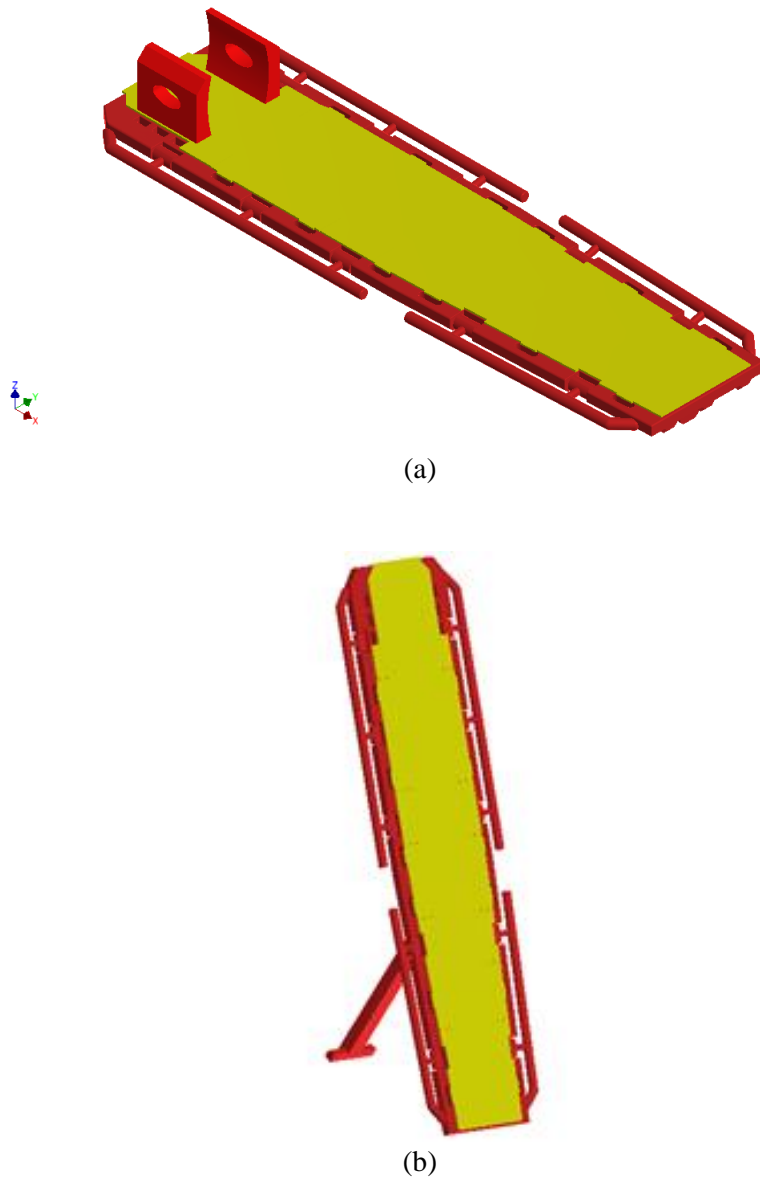


Figure 5. (a) Spinal Board with Head Immobilizer.
(b) Spinal Board in Standing Position with Vertical Buffer.

4. Conclusion

This study redesigned a spinal board that considered ergonomics criteria, using the integration of function analysis and trimming method. The approach is believed can provide an effective process in product development and create a concept design that can fulfill the users' needs. The study resulted in an alternative design of an ergonomics spinal board with better performance in reducing injury and

increasing comfort and safety and fulfilling the users' needs, especially in Indonesia. Design improvements generated from this study are as follows: (1) The application of fiberglass with epoxy material as the primary material for the board; (2) The board is covered by EVA foam and coated with Taslan fabric; (3) Additional feature of head immobilizer which can be released when not needed and is fitted with foam to make it more comfortable; (4) The availability of vertical buffer which serves to position the product in a vertical state.

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