

ANALYTICAL STUDY OF BABY BED DESIGN WITH ERGONOMICS AND SAFETY STANDARDS APPROACH

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ABSTRAK

Penelitian ini bertujuan untuk menganalisis perancangan tempat tidur bayi dengan pendekatan ergonomi dan standar keselamatan guna menjamin kenyamanan, keamanan, dan kesehatan bayi selama tidur. Perancangan tempat tidur bayi merupakan aspek krusial karena berkaitan langsung dengan tahap pertumbuhan dan perkembangan fisik bayi. Desain yang tidak tepat berpotensi menimbulkan risiko cedera, gangguan tidur, hingga masalah kesehatan seperti plagiocephaly (sindrom kepala datar). Metode penelitian yang digunakan meliputi studi literatur terhadap desain produk yang telah ada, analisis standar keselamatan yang berlaku, wawancara dengan ahli kesehatan anak, serta evaluasi terhadap produk komersial di pasaran. Analisis difokuskan pada aspek struktural, pemilihan material, dimensi produk berbasis antropometri bayi, serta kelengkapan fitur keselamatan. Hasil penelitian menunjukkan bahwa perancangan tempat tidur bayi harus memenuhi prinsip ergonomi untuk mendukung postur tubuh bayi, menggunakan material yang aman dan bebas zat berbahaya, memiliki konstruksi kokoh dengan sistem pengaman yang meminimalkan risiko terjepit atau terjatuh, serta menyediakan ventilasi yang baik dan kemudahan perawatan. Selain itu, penerapan standar keselamatan yang teruji menjadi faktor penting dalam meningkatkan kepercayaan dan rasa aman bagi orang tua. Dengan pendekatan ergonomi dan standar keselamatan yang terintegrasi, desain tempat tidur bayi diharapkan mampu memberikan perlindungan optimal serta mendukung kualitas tidur yang sehat bagi bayi.

Kata kunci: perancangan produk, tempat tidur bayi, ergonomi, standar keselamatan, keamanan produk.

ABSTRACT

This study aims to analyze the design of baby cribs using an ergonomic approach and safety standards to ensure infants' comfort, safety, and health during sleep. The design of baby cribs is a crucial aspect as it is directly related to infants' growth and physical development stages. An inappropriate design may pose risks of injury, sleep disturbances, and health problems such as plagiocephaly (flat head syndrome). The research methods include a literature review of existing product designs, analysis of applicable safety standards, interviews with pediatric health experts, and evaluation of commercial products available on the market. The analysis focuses on structural aspects, material selection, product dimensions based on infant anthropometry, and the completeness of safety features. The results indicate that baby crib design must comply with ergonomic principles to support proper infant posture, use safe and non-toxic materials, incorporate sturdy construction with protective systems that minimize the risk of entrapment or falls, and provide adequate ventilation as well as ease of maintenance. Furthermore, the implementation of certified safety standards is an important factor in increasing parents' trust and sense of security. By integrating ergonomic principles and safety standards, baby crib designs are expected to provide optimal protection and support healthy sleep quality for infants.

Keywords: Product design, baby crib, ergonomics, safety standards, product safety

INTRODUCTION

Sleep is a key physiological need for babies that plays an important role in neurological, cognitive, and physical development [1], [2]. The quality of a baby's sleep is greatly influenced by the sleeping environment, including the design of the baby crib used [3]. Therefore, the design of the

crib must consider ergonomic aspects and safety standards to minimize the risk of injury and health problems.

Various studies show that the design of baby sleep products that do not meet standards can increase the risk of *sudden unexpected infant death* (SUID), *entrapment*, and falls [4], [5].

Factors such as the stiffness of the mattress surface, the distance between bars, the stability of the structure, and the presence of additional accessories have a significant influence on the safety of the baby [6], [7]. Biomechanical studies also emphasize that the slope of the sleeping surface and the degree of softness of the mattress can affect the baby's postural and respiratory system control [8], [9].

From an ergonomic perspective, the design of the crib should be adjusted to the baby's anthropometric data to support optimal posture during the growth period [10]. An ergonomic approach in children's product design has been shown to improve comfort while reducing the potential for musculoskeletal disorders later in life [11]. In addition, the selection of materials that are free of harmful substances and have good air circulation is an important factor in maintaining the health of the baby [12].

International safety standards and baby product regulations have been developed to reduce the number of accidents related to children's furniture [13], [14]. The implementation of such standards in the design process has been shown to significantly improve the safety level of the product [15].

Based on this description, an analytical study is needed that integrates ergonomic principles and safety standards in the design of baby beds to produce a design that is safe, comfortable, and in accordance with the needs of baby development.

RESEARCH METHODS

To ensure that the research runs systematically and in accordance with the conceptual framework that has been prepared, a *flowchart* of the research process is designed as shown in the figure. The flowchart depicts the stages of research from problem identification to the preparation of the final report, with an integrative approach between ergonomic principles and baby product safety standards.

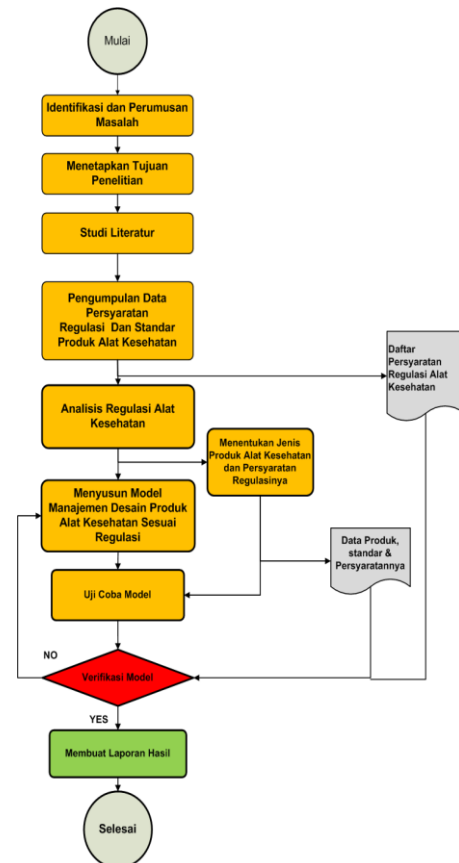


Figure 1 Research Flow chart

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The first stage is the identification and formulation of the problem, which is carried out by examining the phenomenon of safety risks in baby sleep products based on the findings of the literature and incident data of children's products [16], [17]. Furthermore, the purpose of the research was determined, which focused on developing a model for designing baby cribs based on ergonomics and international safety regulations.

The next stage is a literature review, which aims to collect theories and previous research results regarding infant anthropometry, sleep biomechanics, children's furniture design, and crib safety standards [18]–[20]. The literature shows that factors such as mattress stiffness, bar

spacing, structural stability, and toxin-free materials are important parameters in infant sleep safety [21], [22].

After that, data on regulatory requirements and product standards were collected, referring to international standards such as ASTM F1169 and EN 716 which regulate the dimensions, structural strength, and safety requirements of baby cot products [23], [24]. This stage is followed by a regulatory analysis, to identify product classifications and technical requirements that must be met.

Based on the results of the analysis, a product design management model was prepared that integrates the principles of ergonomics and safety. An anthropometry-based ergonomic approach of infants is applied to ensure optimal postural support and comfort [25], [26]. The designed model then enters the trial and evaluation stage, which aims to assess the suitability of the design against structural parameters and safety standards [27].

The model verification stage is carried out to ensure that all technical and regulatory requirements have been met. If it is not suitable, then design improvements (iterative) are made. If the criteria have been met, the research is continued to the final stage, namely the preparation of a report on the results of the research.

With this systematic and regulation-based research flow, it is hoped that the resulting baby bed design will be able to provide optimal protection, improve the quality of baby sleep, and meet internationally applicable safety standards.

RESULTS AND DISCUSSION

In this study, two alternative baby bed designs with different materials were developed, namely steel-based design (Case A) and wood-based design (Case B). This approach aims to conduct a comparative analysis of the structural, functional, and compliance requirements of ergonomics and safety standards of each material.

In **Case A**, the design of the steel-based crib was carried out through a *redesign* process of PT. X's existing products. This approach allows for the identification of design deficiencies in advance as well as a more comprehensive integration of technical and regulatory requirements.

Meanwhile, in **Case B**, the design of a wood-based baby bed was developed based on the analysis and synthesis of data from various commercial products currently circulating in the market. The data collected includes product dimensions, structural configurations, safety systems, and commonly used material specifications. This approach aims to produce a design that is adaptive to industry practices, while still meeting the principles of ergonomics and safety.

Based on the design requirements that have been formulated (Requirements 1 to Requirements 10), the overall function of the product can be expressed as a system capable of providing a safe, comfortable sleeping environment and supporting infant care activities. In **Case A**, the overall function of the product is formulated as: *A means of lying down the baby that allows safe transfer, provides optimal sleep comfort, and makes it easier for parents to lift the baby during the breastfeeding process.* Meanwhile, in **Case B**, the overall function of the product is formulated as: *A baby bedding facility that can be used until the baby is able to sit or stand on its own, ensuring safety from the risk of falling, scratching, irritation, or pinching, and providing sleep comfort and ease of mobilization when needed.* Referring to Pahl and Beitz's theory of systematic design, the overall function is further elaborated into a *functional structure* that describes the relationship between inputs, transformation processes, and outputs of the product system. The structure of this function is the basis for the development of design concepts as well as the evaluation of alternative solutions, as shown in the following Figure.

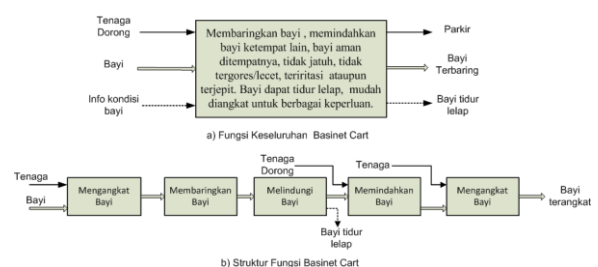


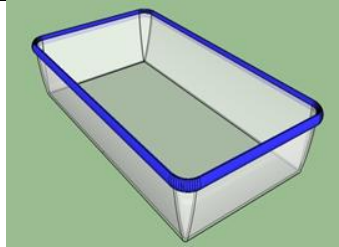
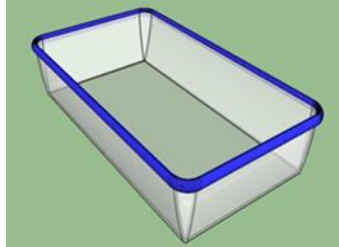
Figure 2 Overall Function and Function Structure of Case A

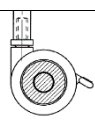


From the continuity function and the structure of the case A function, the solution of each product function can be determined as shown in Table 1.

Figure 3. Overall Function and Function Structure of Case B

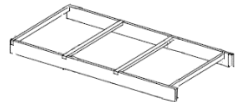
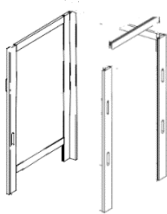
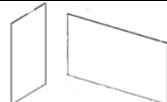
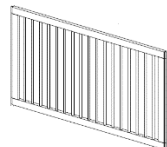
Table.1. Functional Solutions of Case A

No	Function	Solution	
1	Lifting the Baby	Hand power	
2	Laying down the baby	Bassinets	
3	Protecting the baby		
	3.1 Withstanding the baby's heavy weight	Retaining frame	
	3.2 Protects against scratches	Bassinets made of plastic material with smooth surface	
	3.3 Protects against irritation	Cashew	
No	Function	Solution	
4.	Moving the baby		

	4.1 Power	Hand thrust style	
	4.2 Moving the bassinet and baby	Castor	
5.	Lifting the baby		
	5.1 Parking	Braking	Castor with brake 
	5.2 Lifting	Hand style	

From the overall function and function structure of case B, the solution of each product function can be determined as shown in the Table above

Table 2. Functional Solutions of Case B

No	Function	Solution	
1	Lifting the Baby	Hand power	
2	Laying down the baby	Cots	
3	Protecting the baby		
	3.1 Withstanding the baby's heavy weight	3.1.1 Retaining frame	
		3.1.2 Leg Frame	
		3.1.3 Boards for side and back walls	
		3.1.4 Access door	
	3.2 Protects against irritation	Matras	
No	Function	Solution	
4.	Baby Activities		

	4.1 Rolling + tengkurap	Material	Fine finish wood
	4.2 Crawling	material	
	4.3 Pulling the door	Bars	Enough distance for the baby not to be pinched or slip out the door
5.	Moving the baby Lifting the baby		
	5.1 Power	Hand lift style	
	5.2 Moving the baby		

Functional Prototyping

From Figure 4. Showing the design of the form and the detailed design is then proven that the design idea can indeed be realized in physical form and its functional function can be shown through the operation of the physical form. This prototyping activity is proof of the realization of the idea by making all components that are planned to be made and buying all components that are planned to be purchased, then from the components that have been made or purchased, the assembly process of this product design is carried out with the following results:

Product prototype (case A)



Figure 4 Product prototype Case A (*Basinet Cart*)

Discussion of Research Results

The need for medical devices that can be produced by local industries is a strategic issue in strengthening national independence in the health sector. Medical device products are included in the category of products that are strictly regulated, both at the national and international levels, because they are directly related to the aspects of safety, quality, and benefits for users. Therefore, every product produced must meet regulatory requirements that include safety, performance,

and functional suitability (*intended use*) before it can be distributed to the public.

In the context of strengthening the competitiveness of the domestic industry, the government encourages increasing the capacity of local industries to be able to control the domestic medical device market more significantly. These efforts require comprehensive mastery of technology, especially in the aspects of management and development of medical device products. Product development in this sector not only focuses on technical innovation, but also on the integration of regulatory requirements, risk management, quality control, and design validation.

Through this study, a study was conducted on the medical device product development management model which is designed to integrate all stages of the process, starting from product idea initiation, conceptual design, design development, to readiness to the production stage. The model developed seeks to capture all the main activities in the product development cycle in a systematic and structured manner, so that it can become an operational framework for local industries.

As a form of verification, the model was tested through case studies on product design with a relatively simple level of complexity. This approach aims to prove that the model can be implemented practically and operationally. However, considering that the scope of medical device product development is very broad and involves advanced stages such as clinical trials, certification, registration, and mass production preparation, in this study, model proof is limited to the functional prototype development stage.

The results show that up to the functional prototype stage, the proposed product development management model can be effectively operationalized. The next stage towards a *market-ready product* requires further study and can be the next research agenda.

CONCLUSION

This research succeeded in producing a prototype of a convertible *baby crib* that is designed to keep up with the changing needs of babies while extending the life of the product from 6 months to up to 3 years. This product is developed with two configuration modes, namely *bedside crib* mode for babies up to 6 months of age and *standard crib* mode for children aged 6 months to 2 years, so that it can adjust the function according to the baby's growth and development stage. The design and development of this baby cot product complies with the requirements of international safety standards, especially EN 1130 Part 1 and Part 2, which emphasize aspects of construction safety, comfort, and protection against the risk of injury such as falling, scratching, and pinching. This product allows babies to lie down, play, sit, kneel, and withdraw safely, as well as facilitate mobility and bed movement according to the baby's care needs. The resulting design and development model is also designed to be implemented by small and medium-sized industries without burdening production capacity, thereby supporting the strengthening of local industries in the medical devices and baby supplies sector. Model verification through a simple product design case study shows that this model can be effectively operationalized in the functional prototype stage. However, the *usability test* identified several deficiencies in the selection of materials and supporting components that affected the optimization of product functionality. Therefore, further studies are needed for product design refinement, followed by more in-depth validation through the creation of professional prototypes and commercial prototypes to the stage of product launch to the market. With this product innovation, it is hoped that the efficiency and functional value of the crib will increase, while supporting the growth of the local medical device industry based on ergonomic approaches and safety standards.

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