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Function Combined Method for Design Innovation of Children's Bike

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Abstract: As children mature, bike products for children in the market develop at the same time, and the conditions are frequently updated. Certain problems occur when using a bike, such as cycle overlapping, repeating function, and short life cycle, which go against the principles of energy conservation and the environmental protection intensive design concept. In this paper, a rational multi-function method of design through functional superposition, transformation, and technical implementation is proposed. An organic combination of frog-style scooter and children's tricycle is developed using the multi-function method. From the ergonomic perspective, the paper elaborates on the body size of children aged 5 to 12 and effectively extracts data for a multi-function children's bike, which can be used for gliding and riding. By inverting the body, parts can be interchanged between the handles and the pedals of the bike. Finally, the paper provides a detailed analysis of the components and structural design, body material, and processing technology of the bike. The study of Industrial Product Innovation Design provides an effective design method to solve the bicycle problems, extends the function problems, improves the product market situation, and enhances the energy saving feature while implementing intensive product development effectively at the same time.

Key words: children's bike, function combined method, ergonomics, function transformed

1 Introduction

An investigation into the stroller market reveals many design problems. First, the technological level of manufacturing strollers in China has reached a certain scale and level. The number of modern equipment and workshops is increasing, and the design level of children's bikes is enhanced constantly[1–2]. However, in the field of children's bike design, copying or imitation is a serious issue. As a result, product homogeneity in the market is gradually increasing(e.g., baby walkers, baby perambulators, and children's bikes[3–4]). Different types of children's bikes may adopt different manufacturing technologies. Nevertheless, the same kind of product is not much different in terms of manufacturing, technology, and equipment.

From birth to adolescence, children are at the peak of growth, and their body size rapidly changes. Thus, children's products have short life cycles[5]. Designers should develop more rational designs that focus on human anthropometrics and product life cycle, which may reflect the greatest degree of product value.

Research on multi-function bicycles is limited to the search for correlative and international references, which present more patents on technological innovations. For example, the design of racing and body-building bikes that can accommodate more people necessitates solving the problem of combining several functions to fit user requirements. Similar references on children's bikes are scarce.

This situation can be viewed from two aspects. From the perspective of multi-function bicycle research, XU[6], WU, et al[7], and WOSTYN[8] researched and designed some multi-function bikes by improving structure. Some were body-building bikes fixed on its frame and vertical, and others designed with folding frame. From children's bike research point, ZOU, et al[9], HE, et al[10], researched children's requirements and designed some new bikes, such as multi-purpose stroller, assistant little bike. In a word, some innovative ideas are worth references which maybe apply into children's bike innovative design.

However, fewer studies concerning bicycle design based on the multi-function method, a concept derived from industrial design, have been conducted. LEFEVER, et al[11], proposed the function analysis system technique(FAST), which enabled the conversion of ideas into product design through top-down system analysis. WU, et al[12], used FAST to analyse the bike's functions, and shaped matrices to design a style that combined a riding bike and a swing

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bike. OTTO, et al[13], applied a product black box to set a function tree and introduced the development of innovative products through examples.

This paper proposes a convenient multi-function method and the modular function is gotten from the different demand for bicycle-body added as mechanical conversion. Based on the industry design, the design of child's multi-function bicycle-body solves not only the wide range problems but also the short period problems, etc.

2 Function Combination Method of Design

Function combination is a simple and rational product innovation design method. It is an important consideration of customers when choosing products[14]. Thus, the diversification of demand determines the generation of function combined products.

With this method, some existing problems of children's bikes can be solved, such as repeat function and having many classes. For users, multi-function products can satisfy their needs. The study analyses the function sand proposes a method to superimpose and transform the functions. Based on this method, current manufacturers can produce function-intensive products through appropriate technology. Adhering to energy saving and environmental protection principles, the novel design method is used in the field of industrial design to develop feasible design concepts[15–16]. In 2002, a product was developed combining the features of an electric vehicle, motorcycle, and bicycle. In 2012, Hohai University participated in Jiangsu Province's mechanical innovation design competition. The design team developed a product with a multi-function design used for riding, shopping, and infant seating for a novel mechanical deformation of the body (Fig. 1), in which the product innovation design method has a guiding role.

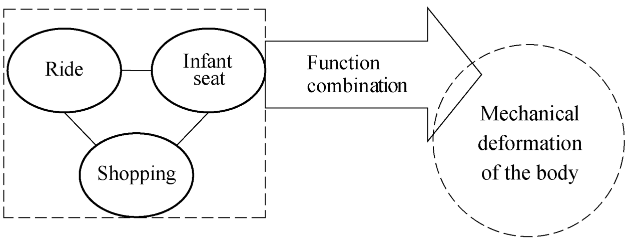


Fig. 1. Process of the three function combined bikes from Hohai University

3 Child Research

3.1 Relationship between child and bike

Children use their bikes or wheeled devices only for a short period because they easily outgrow them. A baby stroller can be used for a maximum of two to three years or when the baby is five or six months to three years old. A baby walker assists children in their 7th or 8th month on learning how to walk, and its use is good for about a year. Other types of wheeled devices for babies also have similar problems. This study analyses children's bikes using the function combination method. Then, the results are organised and summarised according to function styles and age group(Table 1)[17].

Table 1. Age groups and function styles of different types of children's bikes

Age group	Type of bike	Main form
5 months to 3 years old	Baby stroller	Hand push: fold, wheel structure
7 months to 1 year old	Walker	Glide: rotational structure, entertainment form
1–3 years old	Three-wheeled stroller	Hand push: three-wheeled, entertainment form
3–5 years old	Tricycle or four-wheels	Ride: entertainment form, rotational structure
After 5 or 6 years old	Scooter	Glide: entertainment form, rotational structure
After 7 or 8 years old	Two-wheeled bicycle	Hand push: fold, wheel structure

In Fig. 2, the different characteristics of bikes, as shown in Table 1, are combined in pairs, such as baby stroller and tricycle, and scooter and bicycle.

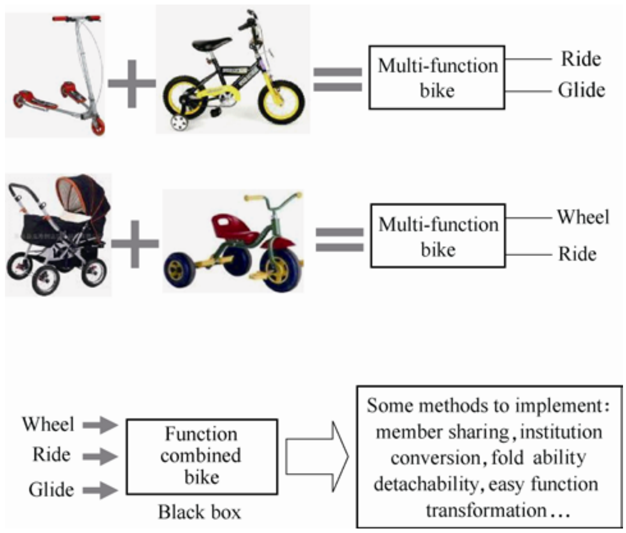


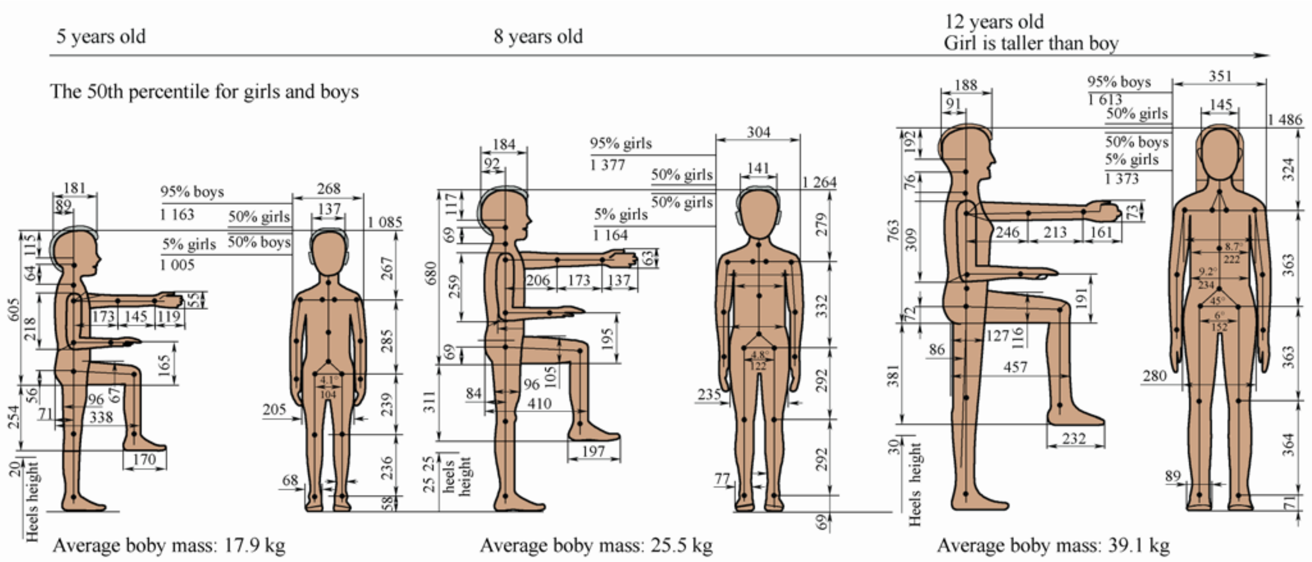
Fig. 2. Function combined forms of the different types of children's bikes

Children aged 5 to 12 years old are selected as target users. The function combined product design considers the characteristics of a scooter and a bicycle. Combining the characteristics of a scooter and a bicycle produces a multi-function bike (scooter + bicycle = multi-function bike).

3.2 Children's size on ergonomics for bike

Product design for children is a process of innovation and improvement in developing products that children can use. The child is at the centre of the design of any product specifically intended for children. Designing products for children takes full account of child factors. Applying ergonomics in product design and development plays a key role in the production of high-quality products[18–19].

Children grow rapidly from ages 5 to 12, and their body size can increase by 5 cm to 6 cm. However, the ergonomic dimensions of body size cannot be extracted from normal fixed groups[20]. To determine the appropriate size of a child's bicycle, separate body sizes are shown for girls and boys in Fig. 3, with the 50th percentile for girls and boys aged 5, 8, and 12 (the grouping is not statistically based on gender because the size disparity between girls and boys is unnoticeable at this stage). Human height noticeably increases by about 40 cm from ages 5–12. If the range value of height is chosen, the 5th percentile of young girls and the 95th percentile of young boys are chosen, and the interval value of height falls between 1 005 and 1 613 cm. As a result, the difficulties that designing entails increases, and this interval value of height is much greater than that from the 5th percentile to the 95th percentile of adult males and females. Therefore, a rational selection of children's size from age 5–12 and data processing are necessary to keep up with the ergonomic requirements of bicycle design.



(a) Ergonomic dimension on the 50th percentile for girls aged 5 years old
(b) Ergonomic dimension on the 50th percentile for boys aged 8 years old
(c) Ergonomic dimension on the 50th percentile for girls and boys aged 12 years old

Fig. 3. Ergonomic dimension on the 50th percentile for children aged 5 to 6years old or 11 to 12 years old (mm)

To accommodate requirements for different ages, the value on the 50th percentile is selected on the basis of child's bicycle size. First, the values can be separately set to M_{50}, M_{50}, and L_{50} on the 50th percentile for girls and boys aged 5, 8, and 12. These values are calculated by determining the mean of ages 5–8 and that of ages 8–12. Second, by setting $a=(M_{50}+N_{50})/2$, $b=(N_{50}+L_{50})/2$, the interval values from a to b can be obtained. The specific numerical values are listed in Table 2.

Table 2. Size setting for bikes for children aged 5–12

Size name	5 years old M_{50}	8 years old N_{50}	12 years old L_{50}	Sitting size a–b
Height	1 085	1 264	1 486	1 175–1 375
Sitting height	338	410	457	374–434
Shoulder breath	268	304	351	286–655
Height from elbow to shoulder	218	259	309	239–284
Hip breadth	205	235	280	220–258
Foot length	170	197	232	184–215
Foot breadth	68	77	89	73–83
Height from thigh back to heel	254	311	381	283–346
Arm length	437	516	620	477–568

The body dimensions of children at the peak of growth rapidly change. Thus, children outgrow the products they use faster. Existing products for children have short product life cycles. Product designers for children need to develop a rational design scheme that can maximise product value.

4 Function Combination Method Applied

4.1 Typical design case

The proposed design combines the various characteristics of a scooter and a tricycle, particularly the function and structure of each type. The design also incorporates ergonomic features using human–machine engineering principles. The designers[21] consider the aesthetics or appearance of the design using a multi-dimensional sketch, a program selection, and a detailed design to develop a portable multifunctional bike for children.

Finally, a realistic three-dimensional rendering using the Pro-Engineering[22]. software of the product is developed The proposed design of a portable multi-function children's bike is discussed below.

The multi-function bike combines the functions of gliding and riding, and conversion from one function to another can be made between the handles and the pedals. Fig. 4 shows the proposed design that combines the features of a frog-style scooter and a tricycle as well as the conversion from a tricycle to a frog-style scooter. To convert the tricycle into a scooter, the smaller wheel found on the handle is interchanged with the larger front wheel through a spring control. The main structure of the bike is inverted, and the smaller wheel is attached to the former position of the larger wheel. The upper handles and the foot pedals are also interchangeable.

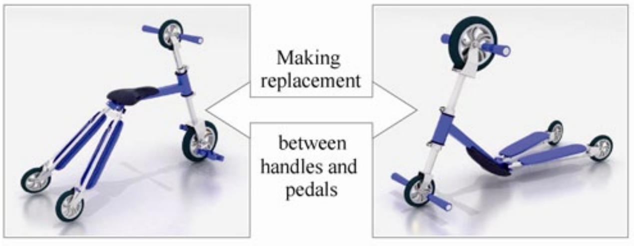


Fig. 4. Interchangeable way

Fig. 5 shows how the multi-function bike is converted from a tricycle to a scooter. The bike functioning as a scooter has the large front wheel close to the torso. The handlebar and the pedals can be interchanged by removing two metal plates and two screws and by assembling them again to the desired function, making dismantling simple and convenient.

4.2 Setting structures of parts and materials

The reference structure information can be determined by choosing the typical scooters and bikes available in the market and disassembling them repeatedly. The structure and the manufacturing technology of the design project can also be established[23–25]. The structures are presented and described in Table 3.

4.3 Materials and process technology

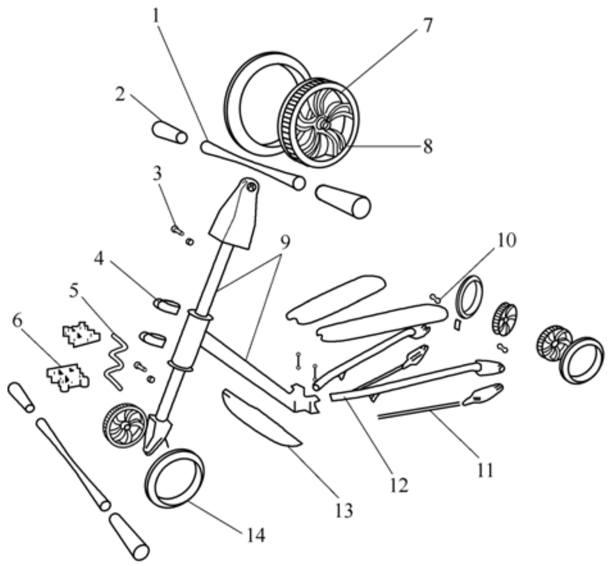
After analysing the materials and the processing technology involved in the production of children's bikes in the market, the designers combine price and other factors to determine the materials required for the final project. Fig. 6 shows the materials and the distribution of the components.

Fig. 5. Conversion from a tricycle to a scooter(two functions)

Table 3. Presentation and description of each structure

Reference structures	 Increasing the friction between the external and internal tubes stabilises the height of the handle. After adjusting the tube to the desired height, the tube can be fixed in place	 Centre bolt can be rotated or fixed	 Centre spring fine tunes the wheel direction	 Rear wheel, centre spring, and foot pedals also functioning as handle bars are connected through the centre axis
Setting structures	 Upper and lower screws control the position of the bike frame, thus avoiding frame movement along the middle axis	 Hand and foot pedals are interchanged and connected by threaded connections to change bike functions	 Lower part of the pedal is connected to the wheels by a metal spring, which regulates the wheel direction when used as a scooter.	 When the bike functions as a tricycle, the pedal angles are fixed in place using metal plates, making conversion and dismantling easy and convenient

ABS materials have low-temperature resistance, impact resistance, low creep, excellent dimensional stability, easy processing, and other properties. Thus, the pedals and the handles are made from ABS plastic. The wheels are made from polyethylene ethylene[26], which has corrosion resistance and excellent electrical insulation; glass fibre reinforced type is also available. Screws and other small parts are made from aluminium alloy[27] of the body frame is mostly made from metal iron.



No.	Parts	Material	Processing
1	Handle lever	Iron spray painting	Plastic forming
2	Handle	ABS	Injection molding
3	Nut	Aluminum alloy steel	Compression molding
4	Locknut	Medal	Stamping forming
5	Brace	Iron spray painting	Hammer forging
6	Pedal	ABS	Plastic forming
7	Wheel	Iron spray painting	Stamping forming
8	Rung	Iron spray painting	Sheet stamping
9	Body	Iron spray painting	Plastic forming
10	Footplate	ABS	Injection molding
11	Spring	Iron spray painting	Compression molding
12	Prop stand	Iron spray painting	Plastic forming
13	Saddle	ABS	Extrusion molding
14	Tyer	PE plastic(polyethylene)	Compression molding

Fig. 6.　Materials and process technology of the design project

5　Conclusions

(1) The project proposes an innovative product design using a rational multi-function method of design through functional superposition, transformation, and technical implementation. The project also analyses the combined functions of different bikes.

(2) From the view of ergonomics, the body dimensions of children aged 5–12 years old are extracted. The size for the multi-function bike is also established.

(3) The study proposes a design for children's bikes that can perform two functions, namely, gliding and riding. The two functions are made possible by interchanging the handles and the pedals. Bike body material and processing technology are also established.

(4) The function combination method is not only applicable in the innovative design of children's bikes but also in extending the service life of the product, introducing energy saving features, and developing intensive concepts.

References

[1] YANG Yin, NIE Guiping, YANG Qi. Household consumption behavior and design of pre-school product[J]. *Journal of DNGHUA University (Natural Science Edition)*, 2010, 36(4): 433–437. (in Chinese)

[2] JIANG Wen. System design—A way for combining the function of products[J]. *Konstruktion Engineering Design*, 2001, 9(1): 28–30. (in Chinese)

[3] LIN Chyunchau, LUH Dingbang. A vision-oriented approach for innovative product design[J]. *Advanced Engineering Informatics*, 2009, 23(2): 191–200.

[4] TOI Satoshi, SAKAMOTO Kohji, TATSUMI Hiroshi. Stroller behavior and road characteristics on walking routes[J]. *Memoirs of the Faculty of Engineering, Kyushu University*, Japan, 2004, 64(3): 171–184.

[5] ZHU Zhixian. *Child phychnology*[M]. Beijing: People's Education Press, 2003. (in Chinese)

[6] XU Dalai. Multi-functional body-building bike in which cushion is fixed on its frame and vertical shaft is movably hinged with the frame, handle and pedal mechanisms are fastened in the upper part and lower part of vertical shaft: China, CN2912708-Y[P]. 2007-06-20.

[7] WU Hongsheng, CHEN Chunho. Improved structure of multi-function exercise bike: China, Taiwan, TW263124[P]. 1993-09-15.

[8] WOSTYN Lucien. Multi functional bicycle with folding frame|has front wheel fork split into two sections movable relative to each other in order to alter steering column and handlebars height: Belgium, BE1011347-A7[P]. 1999-07-06.

[9] ZOU Yazhuo, LI Yunfeng. Multi-purpose e.g. baby strollers, baby carriage, has insertion pins arranged at two sides of rear part of baby basket inserted in insertion grooves such that baby basket is connected with carriage body: China, CN201580419-U[P]. 2010-09-15.

[10] HE Guiqing, SHEN Yang. Multi-function assistant little bike, has frame provided with fluorescent lamp, and wheel set with brake, where frame is provided with axis installed with drop-leaf sleeved with seat: China, CN201646802-U[P]. 2010-11-24.

[11] LITTLE A. *A reverse engineering toolbox for functional product disassembly and measurement*[D]. Austin: the University of Texas, 1997.

[12] WU Xiaoli, WANG Yuxing. A function combined children bike based on design of FAST method[J]. *Machinery Design & Research*, 2011, 26(1): 98–101.

[13] KEVIN N Otto, KRISTIN L Wood. *Product design: techniques in reverse engineering and new product development*[M]. Shanghai: East China Normal University Press, 2003.

[14] JIANG Ping, ZHAI Jinjin. The integrated innovation of function combination based on axiomatic design[C]//*International Conference on Information Technology for Manufacturing Systems*, Macao, China, 2010: 1 222–1 228.

[15] MURRAY, RYAN-KRAUSE Patricia. Bicycle attachments for children: bicycle seats, trail-a-bikes, and trailers[J]. *Journal of Pediatric Health Care*, 2009, 23(1): 62–65.

[16] POWELL E, TANZ R R. Tykes and bikes: Injuries associated with bicycle-towed child trailers and bicycle-mounted child seats[J]. *Archives of Pediatric & Adolescent Medicine*, 2000, 154(4): 351–353.

[17] LIU C T, LIN B M, PAN J S. Design and development of a zero-emission scooter for Taiwan[J]. *Journal of Power Sources*, 1996, 59(1–2): 185–196.

[18] DING Yulan. *Man-machine engineering*[M]. Beijing: Beijing Institute

of Technology Press, 2005. (in Chinese)
[19] WICHENS C D, JUSTIN HOLLAND J G. *Engineering psychology and human performance*[M]. Shanghai: East China Normal University Press, 2003.
[20] YUAN Baoxiang. *Ergonomics of industrial design*[M]. Beijing: China Machine Press, 2010. (in Chinese)
[21] WU Xiaoli, QIU Tingting. Innovative design and engineering analysis of combined children bike[J]. *Machinery Design & Research*, 2010, 26(6): 124–131. (in Chinese)
[22] SRINIVASAN A Parthiban R. Aurora: A software framework for all-optical network design and analysis[C]//*2009 Innovative Technologies in Intelligent Systems and Industrial Applications, CITISIA, Kuala Lumpur*, MALAYSIA, 2009: 87–91.
[23] QI Yunhui, WANG Shuwang. Product structure element clustering design for energy optimization[J]. *Chinese Journal of Mechanical Engineering*, 2008, 44(1): 161–167. (in Chinese)
[24] WEINERT Jonathan, OGDEN Joan, SPERLING Dan, et al. The future of electric two-wheelers and electric vehicles in China[J]. *Energy Policy*, 2008, 36(7): 2 544–2 555.
[25] KOBAYASHI Hiroshi, KOSEKI Mitsuhiro. A new differential gear mechanism[C]//*IEEE Technical Exhibition Based Conference on Robotics and Automation, Proceedings*, TExCRA, Tokyo, Japan, 2004: 25–26.
[26] HAN Guoming. *Welding technology*[M]. Beijing: China Machine Press, 2007. (in Chinese)
[27] HU Chaohui, CHENG Aiguo. Application of multi-objective optimization of multi-material-multi-part specification composite construction[J]. *Chinese Journal of Mechanical Engineering*, 2010, 46(22): 111–116. (in Chinese)

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