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PRACTICE-LED: DESIGN FACTOR ANALYSIS IN DEVELOPING NEW MOUNTAIN BIKE (MTB) PEDAL

Mohd Shahrizal Dolah[1]*, Mohamad Amaluddin Amran [1], Aminuddin Yusof[2], Shahrul Azman Shahbudin [1], Raja Ahmad Azmeer Raja Ahmad Effendi [1] and Saiful Hasley Ramly [1]

[1]Department of Industrial Design, Faculty of Design and Architecture, Universiti Putra Malaysia, 43400 Serdang, Selangor Darul Ehsan, Malaysia.

[2]Department of Sport Science, Faculty of Educational Studies, Universiti Putra Malaysia 43400 Serdang, Selangor Darul Ehsan Malaysia.

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ABSTRACT

This paper has investigated a practice-led design method for product designers in designing a new mountain bike (MTB) pedal. According to the World Bank, it is estimated, there are already more than two billion bikes in use around the world in 2017 and the number increasing every year. The main objective of the study is to understand the cause of an accident and to provide design factors for a designer in developing a new MTB pedal. Fieldwork done in Malaysia from 2018 to 2020 revealed that, 85.2% of mountain bike riders involved in an accident (physical injuries) during bike event that course by the mishandling of bike pedal. Direct observation and action design research was adopted as the main research method where the author involved actively participating in MTB event to gain the main data. Product design specifications were listed that could help in reducing physical injuries among mountain bike riders (MBR). Eight design factors were listed as the main design priority in the product design specification. The product design specifications (PDS) were used as design guidance for designer in developing a new MTB pedal that could meet the requirement and the preferences of the mountain bike riders.

1. INTRODUCTION

Bicycles are one of the world's most popular modes of transportation. According to the World Bank, it is estimated, there are already more than two billion bikes in use around the world in 2017 (World Bank, 2017). Bicycles are also the most energy- efficient vehicle. Cycling takes one-third the energy per kilometre of walking or running, so the cyclist can travel longer distances (Burke, 2003). Currently, bicycles were use not only for transportation, but also for fitness, competition, and touring. Jamboree (MTB race event) challenge riders to cross a country racing, this style of riding typically implies riding fast with an emphasis on climbing prowess. Distance varies from just a few kilometres to 25km-plus. They are limited educational studies and research undertaken on mountain biking in Malaysia. Most studies are focus on Malaysia core sport e.g.: football, bowling and athletic. For the past 5 years, mountain bike (MTB) has become an extremely popular sports event in Malaysia. Malaysia geographically is ideally suited for mountain biking (MTB) activities. Thus, from recreational, mountain biking has evolved into a popular and highly challenging endurance and high-risk sports. Mountain biking is the sport of riding bicycles off-road, often over rough terrain, using a specially designed mountain bike. The launch of FITMalaysia in 2014 and national sports day 2015 showed the encouragement by the Ministry of Youth and sports of Malaysia towards a healthy and active lifestyle. Although early versions were rather crude, off- bicycles today typically include high strength, lightweight frame with a wide array of available suspension and braking systems. Virtually all aspects of the technology continue to evolve, including part and component, equipment, and protective accessories. There are 4 objectives in this study. 1) to record MTB trail data through MTB event(jamboree). 2) to explore physical injuries among MBR resulted from bike pedal mishandling. 3) to analyse type of bike pedal that commonly used by MBR. 4) to develop design factor in developing MTB bike pedal. Listed objective will be used as guidance for designer in designing new concept of bike pedal.

*Corresponding Author: shahrizal@upm.edu.my
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2. LITERATURE REVIEW

2.1 MTB Background

Off-road bicycles, commonly called 'mountain bikes', have become increasingly popular worldwide since their introduction in the western US in the late 1970s. This popularity is partly because these vehicles ridden on a wide variety of terrain which is not accessible to. As the popularity of off-road cycling has increased, the interest and level of participation in the competitive aspects of the sport also increased. According to Pfeiffer and Kronisch (1995), there are 2 organizations — the National Off-Road Bicycle Association (NORBA) and the Union Cycliste Internationale (UCI) — patron the major cycling events within the US and around the world.

As in Malaysia, most events were organized by state MTB clubs or organizations joined organized with the Ministry of Youth and Sports of Malaysia (KBS), FITMalaysia and local authorities (Ministry of Youth and Sports of Malaysia, 2019).

Mountain biking has evolved into a popular and highly challenging endurance and high-risk sports. According to Jeys (2001), injuries sustained while cycling caused 35 000 emergency admissions and injuries during MTB event and the numbers are increasing every year. Based on Malaysia's geographical track is very difficult for MBR if they are facing physical and mechanical injuries. Through the researcher ground work, one of the main causes of MTB riders injured in accidents is the complexity of bicycle pedal design.

2.2 Specific Injury in MTB

According to Gaulrapp, Weber and Rosemeyer (2001), the risks of injury are 0.49% for cross-country riding and 0.51% for downhill. Injury rates are 0.37 riders per 100 h cross-country and 4.34 riders per 100 h downhill racing. More serious injuries to the head and neck occur whilst falling over the handlebars rather than falling off the bike to the side, which tends to result in lower limb injuries. Other factors of injury are loss of control, high-speed descend and competitive activity, i.e. riders are most likely to be injured racing downhill rather than training. Turning, the loss of traction and mechanical problems can also lead to injury. The commonest injuries in MTB (60–75%) abrasions and lacerations and the commonest sprained is the acromioclavicular (shoulder) joint and musculoskeletal disorder (Lareau and McGinnis. (2011).

Sites and types of injuries of the injuries 45.8% affected the upper extremities, 38.8% the lower extremities, 9.1% the head, and 6.3% the trunk. Skin lacerations, wounds, and contusions accounted for 75.4% of the injuries, followed by joint lesions (9.9%; sprains, ligament tears, and dislocations), fractures (5.5%), muscle injuries (5.4%), brain concussions (2.8%), and dental injuries (0.5%). Overuse injuries reported in 0.5%. Experienced athletes had a higher incidence of joint and bone injuries than first year beginners. Only 14.1% of the injuries were ligament tears. Of these 40% involved the acromioclavicular joint, followed by knee, upper ankle joint, and finger joints. The shoulder region was also a major site of fractures; 24.4% of fractures occur at the clavicle bone, followed by 22.9% at the finger bones. Forearm and wrist joints accounted for 9.4% of the fractures. (Jeys et. all. 2001)

Table 1: Physical Injuries

N=135	
Physical injuries during event - pedal	
Variables	No (%)
Yes	115(85.2)
No	20(14.8)

In addition, fieldwork from 2016 to 2018 with MBR revealed that 85.2 % (table 1) Malaysia MBR involved in an accident during MTB event. Amongst the major causes of the incidents during the event were resulted from bike pedal mishandling.

3. METHOD

3.1. Direct Observation

Direct observation or action research was one of the social inquiry techniques used in this research especially during the MTB jamboree (MTB event). Video recording was used during the observation. According to Dolah (2014), direct observation is very useful when details of an activity need to be access and when interview techniques are unlikely to draw out the required information due to the respondents either not knowing or being unwilling to say during the interview sessions or an activity. The observation conducted from 2016 to 2018 that involved 48 MTB Jamboree (MTB event) throughout Malaysia. Objective of the observation is to observe the type of pedal that used by MBR, to record MTB trail in Malaysia, MBR riding behaviour and unfolding MTB issue.

3.2. Questionnaire

Close-ended question were distributed to 135 MBR. MBR were randomly selected on the day and after the MTB jamboree was conduct. MBR answered the questioners after they have completed their ride. Each session took around 15-25 minutes per MBR and assisted by the researcher. Close-ended survey responses were extremely useful in helping to explain or gain insight into organisational issues but at the same time to generate both interesting and challenging types of text to analyse (Jackson and Trochim (2002). Questionnaires were in digital type of form for facilitating the MBR. The data are collected in order to understand MBR experience, to analyse the problem and technique in mountain bike activities. The data were analysed and group into keywords. The group of keywords than, was generated to produce the design variable as shown in table 4. Objective of the questionnaire is to identify types of physical injuries, types of pedal used and pedal analysis variable.

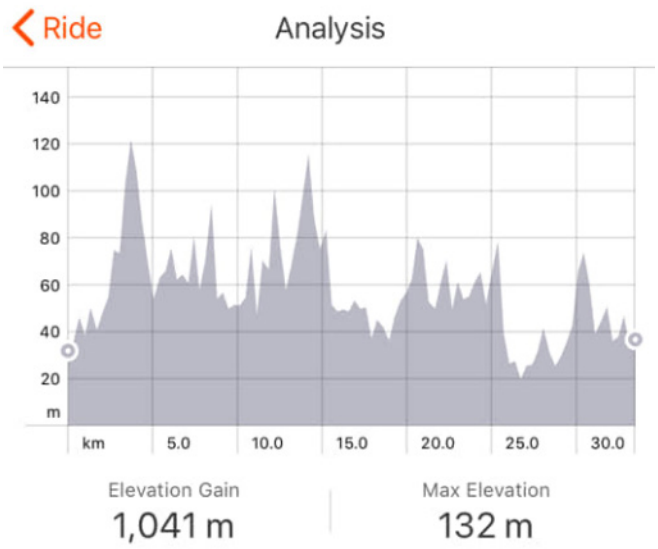
4. DATA COLLECION AND RESULTS

4.1. Database For MTB Trial Malaysia

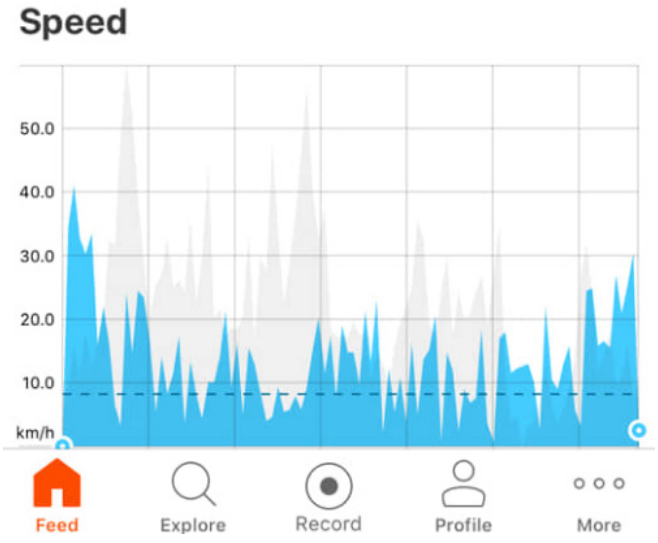
In conducting the action design research, videos and global positioning system (GPS) recorded during the event to gather elevation, riding/moving time, and GPS simulation as shown in figure 1(a) and (b), and figure 2. Figure 1(a) shows the maximum and minimum elevation gain that represent trail level of difficulty. Figure 1(b) shows minimum and maximum speed levels that have be reached by MBR.

An observation was an essential element to understand an ongoing behavior, process and outcome of an unfolding situation. Taylor-Powell and Steel (1996) stated that, "Seeing" and "listening" are the keys to observation. 48 MTB trail were recorded and uploaded in MTB trail Malaysia database for future references for others MBR. STRAVA© and REALIVE© application were use as tools to record the trail analysis and GPS simulation.

Figure 1:



a) Elevation analysis



b) speed analysis

Figure 2: *GPS simulation.*

4.2. MTB Physical Injuries

Close-ended questions used to identify MTB injuries. The injuries listed in table 2 are the types of injuries caused and arising from mishandling of bicycle pedals. Injuries divided into minor and major categories. Minor injuries categorized when it is only necessary to treated by a medical assistant at the event location, while major injuries are categorized into a severe injury that should be taken to a hospital for certain treatment.

Table 2: *Type of Physical Injuries*

N=135

Type of physical injuries	minor	major
Variables	N135 (100%)	N135 (100%)
Cramp	80(59.1)	
Wound	47(34.8)	
Bruises	27(20)	
Hydration	4(3)	
Broken muscle		60(44.4)
Broken bone		24(17.7)
Slip bone ligament		13(9.6)

Finding in table 2 revealed that cramp (80(59.1%)) were the most common physical injuries during MTB events followed by wound (47(37.8%)). Both were group in minor physical injuries. While the broken muscle (60(44.4%)) and broken bone (24(17.7%)) were group in highest major physical injuries. Through researcher direct observation during the MTB event, almost all of the above injuries are cause by MTB pedal that resulted to other physical injuries.

4.3. Pedal Analysis

Action design research were adopted, the researcher rode and participated in the event to gather the main data. Visual recording been made throughout the event to observe type of pedal used by MBR. The researcher also observed MBR riding behaviour (e.g. suitability, safety, handling, efficiency etc). Table 3 shows the type of pedal used by MBR during MTB event.

Figure 3:

a) flat pedal

b) clipless pedal

Table 3: *Type of pedal used by MBR during event*

N = 135	
Type of MTB pedal	
Variables	No (%)
Flat pedal	94 (69.6)
Clipless pedal	41 (30.4)
Magnetic pedal	0 (0)
Others	0 (0)

In table 3 reveal that most of MBR were using flat pedal (94 (69.6%)) as flat pedal were suitable for all, safe to use, easy on/off handling and increase confident as mentioned in table 4. In addition to analyzing pedal types used, questionnaire distributed to MBR after the event. The researchers made an analysis of MBR preferences to use certain pedals on their bicycles as shown in table 4.

Table 4: *Pedal analysis*

N = 135		
Pedal analysis	Flat	Clip-less
Variables	No (%)	No (%)
Suitable for all	135 (100)	30 (22.2)
Safe to use	94 (69.6)	70 (50.7)
Easy on/off handling	135 (100)	45 (33.3)
Increase Confident	130 (96)	60 (44.4)
Comfortable	120 (88.8)	98 (72.5)
Static position	30 (22.2)	135 (100)
Pedal stroke efficiency	35 (26)	130 (96)
Energy efficiency	56 (41.5)	133 (98.5)
Reduce accident (injuries)	100 (74.0)	45 (33.3)
Reduce prolong injuries	54 (40)	100 (74)
Self-align position	0 (0)	135 (100)

In table 4 revealed, the pedal analysis by MBR. Pedal analysis divided into two type of pedal, which are flat pedal and clip-less pedal. The analysis shows that, suitable for all (135(100%)), easy on/off handling (135(100%)), increase confident (130(96%)) and comfortable (120(88.8%)) were the highest preferences from MBR that uses the flat pedal. For the clip-less pedal, static position (135(100%)), Self-align position (135(100%)), Energy efficiency (133(98.5%)) and Pedal stroke efficiency (130(96%)) were ranked the most preferences.

4.4. Development of a New MTB Pedal Design Concept

4.4.1. Design factors

Through the design analysis, the MBR preferences were rank in product design specification (table 5). The Pareto Principle used to determine the most important design factors. The 80/20 rule is one of the most helpful concepts for making a decision. The rule suggested that 20 percent of the known variables would account for 80 percent of the results (Craft and Charles (2002)). Therefore, rank 1 to 4 were choose as the main design factors in developing the new MTB pedal.

Table 5: *Design factors by Rank*

No/rank	Flat pedal	Clipless pedal
Rank 1	Suitable for all	Static position
Rank 2	Easy on/off handling	Self-align position
Rank 3	Increase Confident	Energy efficiency
Rank 4	Comfortable	Pedal stroke efficiency
Rank 5	Reduce accident (injuries)	Reduce prolong injuries
Rank 6	Safe to use	Comfortable
Rank 7	Energy efficiency	Safe to use
Rank 8	Increase accident	Increase Confident
Rank 9	Pedal stroke efficiency	Easy on/off handling
Rank 10	Static position	Reduce accident (injuries)
Rank 11	Self-align position	Suitable for all

4.4.2 Product Design Specification

Eight design factors (rank 1 to 4) were rank the most important factors in developing a new MTB pedal. This to ensure the development of design is according to the MBR need. The mountain bike pedals specifications are as below (table 6):

Table 6: *Product design specification*

	Design factor	Specification
1	Suitable for all	- suitable for any type of MTB sizes - suitable for any level of cyclist
2	Static position	- to prevent collision between ankle and bicycle crank and prolong injuries
3	Easy on/off handling	- pedal system that lets it clipped quickly and easily while riding
4	Self-align position	- to unsure cyclist were leg in static position while paddling – biomechanics
5	Increase Confident	- provide high confidence to riders while riding through various types of resistance while riding without fear of falling or injuries
6	Energy efficiency	- cyclists will be able to maintain foot position while paddling and this will reduce energy consumption
7	Comfortable	- comfort for any type of MTB sizes - comfort for any level of cyclist
8	Pedal stroke efficiency	- Static position can be able to control MBR foot position in a same single direction and this will increase the effectiveness of paddling

5. CONCLUSION

5.1. Contribution For MTB Society

To date, there are no MTB trail database for Malaysia. 48 MTB trails were recorded covering various type of routes in Malaysia during this research project. Data uploaded into MTB Trail Malaysia Facebook as a reference for MBR and MTB event organiser. Data in the form of trail simulation, speed configuration, and trail elevation. Data can be downloaded and as a trail guideline for other MBR to cycling in Malaysia.

5.2. Contribution For Event Organizer

The study have collected data on physical injuries during MTB jamboree. Data is crucial for event organiser for precautionary measures for future event. This data also can be use as medical preparation for medical team in conducting MTB event.

5.3. Contribution For Designer

This project have analysed type MTB pedal used by MBR. There are eight main factors designing on pedals and flat clips as shown in table 5. These design factors analysis can be use as guideline and references for designers in developing a new MTB pedal in the future. The designer can develop the new MTB pedal by following the design factors, from the highest to low rank as stated in the product design specification in table 5. The research reveal that the combination of flat + clip-less pedal could meet the requirements of MBR in Malaysia (Figure 4).

Figure 4: *MBR Pedal Preferences*

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