

# Design of Bicycle Handle using Ergonomic Aspects A Review

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**Abstract**— The name is also called a bike of rural people. Bicycles have evolved significantly over the past decades in pace with technological advancement. However the comfort of cyclists has not much attempted in many designs. Although ample research has been reported on comfort for other means of transportation, cyclist's perception of comfort has received scant attention in the scientific literature. This paper discusses the ergonomic aspects that can be incorporated in the design of a bicycle handle. The first step is to determine which factors contribute to comfort when riding a bicycle which results in human performance and fatigue. It has been found out by means of a survey with enthusiast cyclists that comfort is influenced by factors related to the cyclist (driver position, handle adjustments, body parts). This paper classified into three parts, in the first part the ergonomic aspects of bicycle handle, in second the factors responsible for fatigue and in the third analysis for the comfort positions. The most of the researchers presents there work in change seating position whereas this work focuses on the comfort position of bicycle handles.

**IndexTerms**— Bicycle, Ergonomic study, comfort positions, Fatigue.

## I. INTRODUCTION

A bicycle or bike is a vehicle composed of two wheels held in a frame one behind the other, propelled by pedals and steered with handlebars attached to the front wheel. Karl von Drais of Paris invented the first bicycle in 1817[56,57]. The Draisienne was a steerable bicycle[30]. It was almost entirely made of wood, had no pedals, and was propelled down the street by riders who would push their feet against the ground. The record speed was 15 km/h. [1] Ergonomics is the investigation about humans and work. especially when optimizing the physical contact between humans and engine [100].

Even in this 21st century, the century of modern machines and fast moving automobiles, the cycle has its own identity and importance[54]. Apart from the fact that it is eco-friendly and economical, helping the riders to keep fit and healthy[89]. There have been several changes in the bicycle design since its inception, many attempts were made over the years[78]. Today various designs and styles of bicycles have been introduced like sport/road bicycles, mountain bicycles, BMX (Bicycle Motocross) cycles etc. Throughout the world bicycles are used by school students, University students to go around in the University campus, proletariats to go to work and old aged people for physiotherapy[55]. It is important to keep in mind the widespread use of bicycles necessitates the design should match the anthropometric data to be ergonomic[84]. It is also important to keep a check on the production costs of the bicycle because it is generally considered an economic product[4]. It is crucial to ensure a good industrial design procedure for the bicycle while making substantial ergonomic changes in the conceptual design[60]. An effort has been made to identify the possible inconvenience caused to the rider and propose a design to solve the problems reducing the inconvenience of the bicycle riders [99]. A concise overview of relevant studies is presented here[73]. According to three distinct areas contribute to comfort when riding a bicycle i.e.; environmental, mechanical and biomechanical factors, and physiological factors [96].

A bicycle is a pedal driven , human-powered vechicle with two wheels attached to a frame, one behind the other. Bicycle is a mode of transportation. It is a good exercise machine[74]. It can move around or get good exercise. Comply it is a good source of excercise. Comfort when riding a bicycle can be identified through a number of key elements such as seats, handles, paddle and bicycle frame design[9,10]. More specifically, the goal is to look at the notion of dynamic comfort[55]. Bicycle is a popular and economical mode of human powered transportation[52]. This also enables it to be used as effective equipment towards fitness and rehabilitation[11]. However, bicycling demands one to bend forward while pedaling; this prolonged forward flexion posture may increase the risk of chronic injuries such as musculoskeletal disorders (MSD), compression neuropathies, and so on[13]. Hence, proper bicycle design is necessary to reduce MSD and enhance comfort for rider[79]. Cyclists adopt a round-back or flat-back posture to reach the handlebars by flexing their pelvis and spine. Cyclists who maintain a prolonged awkward posture experience pronounced stress on their shoulder, neck and low back pain[14].

The term 'comfort' might be used to describe a feeling of contentment, a sense of cosines or a state of physical and mental well-being. In engineering term, comfort is generally presumed to be a definable human condition or attribute, with each new innovation bringing society closer to the achievement of ideal indoor conditions[61,76]. Comfort is a concept of rather subjective nature but it can generally be defined as the absence of pain and any other similar nuisance and is usually associated

in the relevant literature with the design and adjustment[3]. Based on the two statements taken from Riding a bike for long distances will cause pain in the hand[41]. The padding on handlebars bicycle is one of the easiest and most effective ways of make bike a more comfortable ride. Some tapes contain a gel-like material integrated into the fabric to make it even more forgiving[34]. Tires are most important part in vehicle using wheels[48]. Type and sizes of tires is important to make riding comfort for rider. All this element is depends on surrounding and area for competitions[37]. Creativity is very important for design process[87]. A design process is usually complex. Ergonomic design for bicycle seat is important to ensure cyclist in comfort and safe[96]. Ergonomics are implemented in every form of design[38]. It is paramount importance that ergonomic factor are taken into consideration while designing product. Ergonomics design means irrespective of the type of product and its function[38].

The principles of ergonomic design are considered in five levels are determined below [32]:-

1. An equipment / machinery must be safe while contact with human beings.
2. An equipment / machinery must not produce harmful effects in human beings over longer periods.
3. An equipment / machinery must be physically comfortable that is, it should not require excessive efforts, both physical and mental or visual.
4. An equipment / machinery should provide mental satisfaction or give a feeling of pleasure to the human being using the same. This must also include the cost price of equipment against the function of the same.
5. Determining the degree of modernity of an equipment / machinery ergonomic considerations must constitute an essential factor of the social profitability of the equipment / machinery. Even at the stage of establishing the design assumptions of an equipment / machinery it is necessary to introduce both ergonomic [12]

The design of bicycles involves the definition of frames of different size and dimensions as well as the definition of the corresponding adjustment ranges for the seat and the handlebar [18,25]. To successfully ride a bicycle in a seated position, many elements should be considered. A minimized frontal area and shape should be presented by the combination of the bicycle and the bicycle rider[20]. The position of the bicycle rider must be comfortable so that the rider can produce requisite high level of effort and performance for long distance[13,15]. Racing type bicycle handlebar is generally constructed of rigid, tubular metal that transfers the vibration from the bicycle directly to rider hands[72].

A Bi-cycle frame should have low weight, high lateral stiffness and moderate vertical stiffness[16]. Because of chain load, frame lateral deformation during pedalling is bigger when the rider pushes on right pedal (a pro rider may apply a force up to two times his weight). Most of the bicycles built today utilize heat treated steel or aluminium or titanium alloy tubing to minimize their weight. The tubes are then welded together to create the desired fork or frame geometry. [51]

In recent years, as manufacturers of racing bicycles and bicycle components have turned to wind tunnel testing to optimize component design<sup>3</sup>, the athletes themselves are now able to purchase time in wind tunnels to refine and perfect their riding positions. Comprehensive reviews by Burke<sup>4</sup> and Lukes cite many efforts which validate the conventional wisdom that the main contributors to overall drag are the rider, the frame including fork and aerobars, and the wheels. Greenwell et.al. have concluded that the drag contribution from the wheels is on the order of 10% to 15% of the total drag, and that with improvements in wheel design, an overall reduction in drag on the order of 2% to 3% is possible. [22]

## II. COMFORT ELEMENT

Ergonomics helps to improve the output and the comfort of bicycle riding[19,27]. When improving the comfort, you can use your power more for bicycle riding and not for struggling against pain[21]. When you improve your output you get more comfort, because your muscles become stronger and you don't sit on the bike like a sack of potatoes[23,24].



Figure 1 Comfort element for short and long range bike ride [17]

There are many elements that should be considered to ensure rider comfort during riding a bicycle based on research, the cyclist makes contact with the bicycle at three locations: the handlebar, the saddle, and the pedals. It is believed that most discomfort is felt near the handlebar and the saddle when riding over a rough surface. [5] Frontal areas and rider positions are greatly affected by the position, shape, and arrangement of the bicycle handlebars. [6] Handlebar grips located in a relatively raised position will encourage a rider to assume a relatively upright riding position. A large frontal area is presented to be comfortable and the relatively large ensuing wind resistance minimizes top speed through the rider may be producing a large amount of pedaling effort [26]. The quality of a racing wheel is related to the combination of several performance parameters with the level of comfort during long cycling tracks. Comfort riding is related to the radial behavior of the wheel assembly, intended as a combination of

tire and rim. Radial properties of wheels are believed to be dependent on tire pressure and construction, rim profile and materials, spoke design and disposition, hub shape and materials. Despite the common opinion among cyclists that the wheel radial properties affect the rider's back comfort. [7] There are many elements that need to be considered in order to get comfortable riding for

long distance rider or competition rider. In this project, only saddle-based elements will be analyzed and discussed. A poorly designed seat will not distribute body weight or reduce pressure effectively over the perineum and thus increase the risk of seat discomfort or injury, which seems to be a common occurrence among cyclists. [8]

The survey connecting Hari Pamboor ( Ambassador of Kerala Health Services , Palakkad ) , five riders who travelled from Kerala to Khardung La ( Mountain peak near Ladakh ) having a distance of 2500 KM in 52 days [28,35] . The Cycle Club Thrissur having 50 riders were also included in this survey. The format of the questionnaire was given in the appendix. The survey carries a Questionnaire having questions regarding

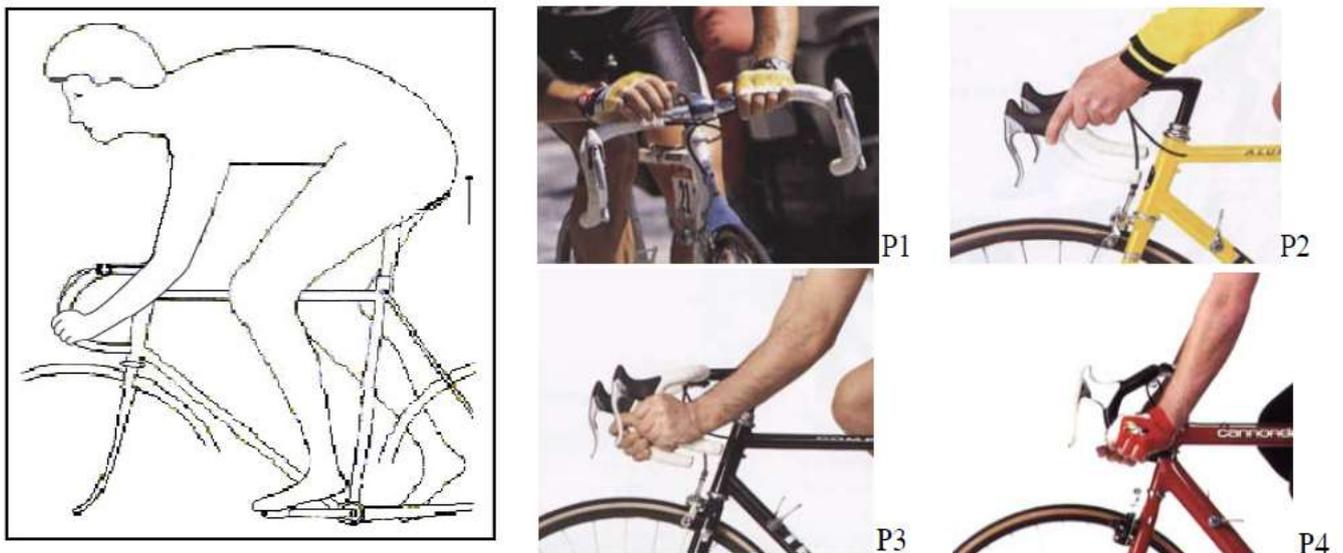
1. Frame material
2. Environment
3. Behaviour
4. Bicycle components

The findings from the survey reveal that the frame material did not contribute to the factors related to comfort [29]. But the speed belongs to the material of the frame. The environment and behavioural elements will affect the comfort but not in terms of ergonomical aspects. The bicycle components were rated as much contribute to comfort are the saddle design, handle bar and the frame [23].

### 3. BICYCLE HANDLE

#### 3.1 Riding posture and holding position

Lightweight and comfortable sensation are the basic design requirements of road racing bike. In order to accommodate various riding postures and reduce wind resistance during riding, a cyclist has four hold positions as shown in figure 1 [4]. Position 1 (P1) is the upper half of the handlebar near the center position; the part of curved on both sides is position 2 (P2); position 3 (P3) is the part of controlling braking and speed change; the part of the end handlebar with straight form is position 4 (P4).



**Figure 2 Riding posture (left) and four holding position (right)**

Cyclist has to use lower riding posture at position 3 and 4 for getting faster speed and reducing wind resistance. In order to disperse pressure happened on palm, the holding position area should as big as possible. Since the handlebar offered four different hold positions, cyclist can change the positions during riding for preventing one posture kept a long time and getting chance to take a rest. In recent years, the shape of handlebar has extremely changed from tube to more complex free form surface due to the application and development of manufacture processes and materials [2]. Therefore, this study aimed at exploring the reasonable contact area on each holding position and comfort of palm [3, 5].

### 3.2 Experimental samples and platform

In order to understand whether the comfort sensation will be affected by the shape of handlebar or not, three test samples are selected from market as shown in figure 2(a, b and c). The test sample, named S1, S2 and S3, have different shape and dimension. The width at position 1 is 4.6cm, 4.0cm and 3.2cm and position 2 is 3.7cm, 3.4cm and 3.2cm respectively. The angle of position 3 is 131 °, 105 ° and 90 ° and the length of position 4 is 7.5cm, 7.2cm and 6.6cm. The comfort sensation experiment is not dynamic test, so that three test samples have sequentially to assemble on the test platform as shown in figure 2(d). All dimensions of test platform will be adjusted according to each tester's characteristics such as tall, the length of arm, and the distance from hip to ground. This is a complicated experience and takes a lot of time[24].



**Figure 3 Test Samples of handlebar**

### 3.3 Experiment process

As mentioned above, the main purpose of this experiment is to evaluate comfort sensation on palm during riding. In order to estimate comfort sensation of each handlebar on four positions, there are 18 testers attending this experiment. These testers' average age is 35 and most of them have more than 8 years experience about riding road-racing bike. For exactly measuring comfort sensation, both methods of subjective questionnaire and recording pressure distribution on palm are conducted. The experiment process is shown in Figure 3[63,67].

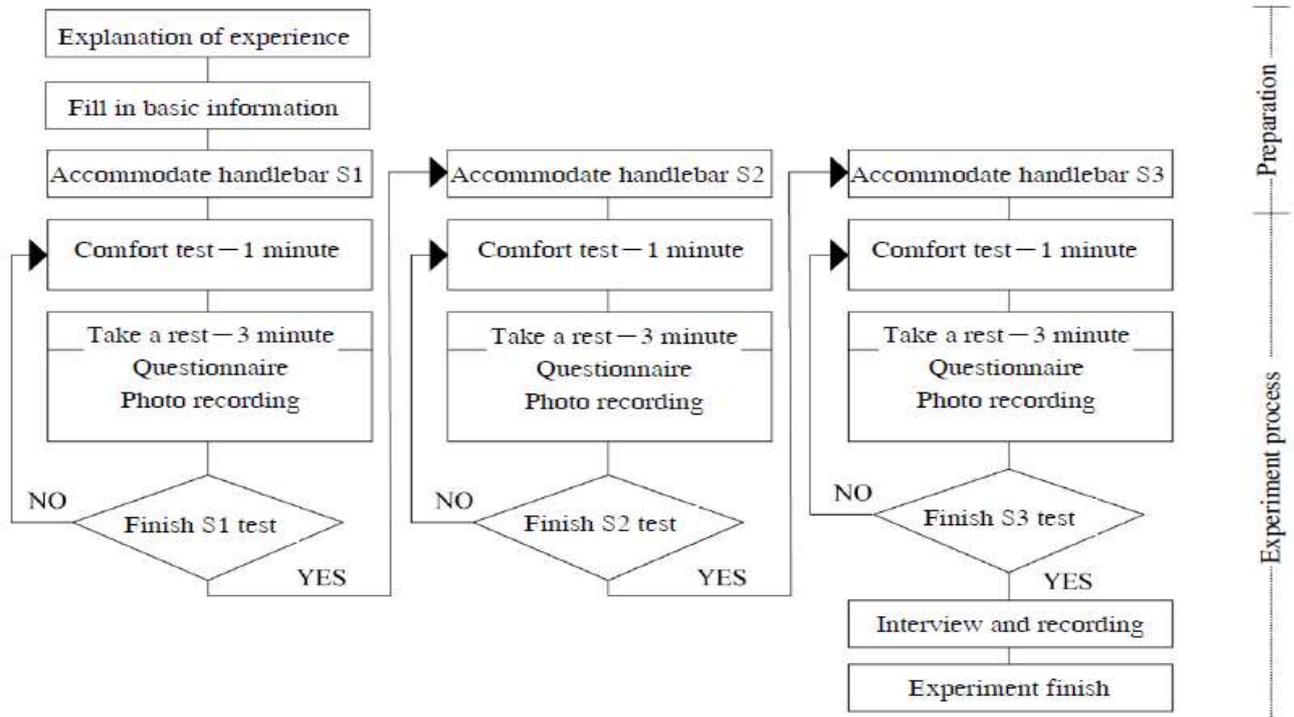


Figure 4 Experimental Process of comfort sensation of palm during riding

### 3.4 Experimental analysis

In table 1, long dot line represents contact area and short dot line specifies pain area. According to design rule and pressure analysis, the pain area on the palm should as small as possible that means a good handlebar can uniformly distribute pressure on the palm. The results showed in table 1 expose that the contact area of the test samples S1 and S2 are almost the same but both are larger than S3, and the contact area of S1 is as big as the palm. Sample S3, compared with S1 and S2, has the smallest contact area. For the pain area discussion, test sample handlebar S1 has bigger pain area at position 1 and the pain area of position 2 to position 3 is the part between the little finger and the wrist. The pain areas of test sample handlebar S2 concentrate on the part from center of palm to rim except position 3. The pain area of the test sample handlebar S3 is the largest in four test samples. Especially at the position 1, the pain area is almost the same with the contact area. Besides, the pain areas of position 2 to 4 have more than half of the contact area. To make a comprehensive survey about the pressure distribution to four test samples, the contact area is the region from the thumb and the index finger to the little finger[75]. The pain area concentrated on the regions of the thumb and the index finger, and between the little finger and wrist. Meanwhile, two nouns, the ratio of contact (RC) and the ratio of pain (RP), had been defined to explain the relationship with comfort sensation. The ratio of contact is defined as the contact area divided by the area of palm, and the ratio of pain is the pain area divided by the area of palm. And then analyze the correlation of RC, RP, the area of palm and comfort sensation by using statistical analysis. According to the analysis data, comfort sensation and contact area has positive correlation at position 1 and 2.

Table 1 Pressure distribution of palm on four holding positions to each test sample

	Sample S1	Sample S2	Sample S3		Sample S1	Sample S2	Sample S3
Position 1				Position 2			
Position 3				Position 4			

## II. ERGONOMIC ASPECTS OF BICYCLE HANDLE

Winston G et. al. describes handles for two commonly used hand tools, the chisel and the off-set pliers, are designed using ergonomic principles. These were sized for both males and females falling in the 5th percentile, 50th percentile and 95th percentile groupings[90,21]. The stresses developed in the ergonomically designed chisel handle while in use were analysed to verify the validity of the design. This chisel handle was then manufactured, and preliminary evaluation using electromyography was conducted. In these tests, the stresses exerted on the flexor and extensor muscles of the arm were measured and compared with those obtained during the use of a conventional handle[36]. Under similar working conditions, results clearly showed that the ergonomically designed handle allows higher working efficiency than existing handles.



**Figure 5 The three important areas to look at in bike ergonomics[17]**

Figure shows the work of the shoulders is also the work of the upper body, up to the end of the breast-spine[77]. The lower back is working with the pelvis and helps to stabilize your body. Proper pedalling is not only the work of the legs, but of the whole body but the investigation is done on legs[61].

Sean P.et. al. investigated assembly of off-road bicycle handlebars with a stem that clamps the handlebar around its circumference would be expected to affect fatigue performance by introducing both assembly stresses and stress concentration[93]. Because the effect of clamping on fatigue performance is unknown and because of the need to insure structural reliability in the stem-handlebar assembly to prevent serious injury, the objectives of the work reported by the present article were fourfold [94]. One was to determine the stresses due to assembly and the stress concentration induced in a handlebar for two different clamp designs (i.e. 1-bolt and 2-bolt), a second was to determine experimentally the high cycle constant amplitude load fatigue lives of the two stem-handlebar assemblies, a third was to determine experimentally the variable amplitude load fatigue lives, and the fourth was to predict the variable amplitude load fatigue life with constant amplitude load fatigue test results. The handlebar was instrumented with strain gages and the assembly strains were measured when the stem clamps were tightened [97,98]. The handlebar was also loaded as a cantilever beam while the applied strains were measured for each assembly. Stresses were computed and the maximum stresses induced by clamping exceeded 200 MPa for both assemblies[50,53]. A method unique to this study was devised to determine the stress concentration at an arbitrary angular location around the circumference of the handlebar and for an arbitrary loading direction in the plane of the bicycle. For a load directed along an angle of  $38^\circ$  (clockwise rotation from horizontal viewed from the right), both stems created similar stress concentration; the location of maximum applied stress was shifted by  $30^\circ$  from the point that would be expected in the absence of assembly and the stress was increased by 40% at this location[30]. The measured fatigue lifetimes for constant amplitude loading were similar for the two stem designs but the variable amplitude load fatigue lifetime for the 1-bolt stem assembly was shorter than that for the 2-bolt stem assembly by 19%[33]. The fatigue lifetimes for variable amplitude loading based on constant amplitude load fatigue test results were predicted to within 3% and 33% for the 1-bolt and 2-bolt stems, respectively. Thus, constant amplitude load fatigue test results can be used to approximate the variable amplitude load fatigue life. However, the ranking of different assemblies may not be accurately indicated by constant amplitude load fatigue data[91].

Paul B. et. al. investigated a simple manufacturing method to obtain bent shape tubes with variable cross-section from fibre reinforced composites with application in high performance handlebars for mountain-bicycles was used[54]. The original procedure is able to assure constant pressure upon the reinforcement material, the result being a compact composite, good quality with an optimum reinforcement degree[42]. Tests and analytical computations, based on classical laminated plate theory delivered the engineering constants that have been used in the finite element simulations of two important safety tests for the handlebar (bending and torsion)[47]. The experimental results obtained for lateral bending test (critical test) are in agreement with the finite element simulations[102].

They find the proposed method allows manufacturing of the bent shape tubes with variable cross-section from fibre reinforced composites[43]. The original procedure by using an inner pressurized elastic mandrel is able to assure constant pressure upon the reinforcement material, the result being a compact composite, well pressed with an optimum reinforcement degree related to the materials used[85]. Traditional methods that use a rigid mandrel manufacturing of bent tubes with variable cross-section as the presented handlebar could not be possible due to the fact that the mandrel cannot be released from the composite tube. The obtained handlebar has a significantly reduced weight (95 g) in comparison with aluminium alloy handlebar with the same dimensions (~250 g). Morphologic analyses revealed a good connection and compatibility between carbon and epoxy matrix. The procedure is relatively simple to put in practice and the costs are reduced[49,50]. The material constants, experimentally obtained, an unsymmetrical orthotropic laminate, are in good agreement with the theoretical results based on the classical laminated plate theory that considered the composite material as a single-layer equivalent orthotropic model[65]. The FE results of the two important tests for the handlebar, requested by the safety requirements and test methods standard of mountain-bicycles, lateral bending test and torsional security test confirm that the carbon/ epoxy composite handlebar undergoes maximum principal stresses of 407.7 MPa in case of lateral bending and 220.6 MPa for the torsion test. Analysing the maximum principal stress values, its direction coinciding with the fibres direction of the second ply, the maximum value was under the ultimate stress experimentally measured[70]. Performing the lateral bending test on the manufactured handlebar test it could be noticed that the handlebar fulfil the safety requirements, being enough strength to undergo the total applied force of 2000 N. The maximum loading force obtained in the experimental analysis has validated the numerical simulation and, in the same time, the material properties were determined by both analytical and experimental way[39]. The safety coefficient is small, reason why, according to the designer options, the handlebar can be strengthened by additional plies inner placed in the maximum stressed area[58].

### III. CONCLUSION

This paper discusses the ergonomic aspects that can be incorporated in the design of a bicycle handle. The first step is to determine which factors contribute to comfort when riding a bicycle which results in human performance and fatigue. It has been found out by means of a survey with enthusiast cyclists that comfort is influenced by factors related to the cyclist (driver position, handle adjustments, body parts). This paper classified ergonomic aspects of bicycle handle, factors responsible for fatigue and analysis for the comfort positions. The most of the researchers presents their work in change seating position whereas this work focuses on the comfort position of bicycle handles. Hence there is a scope to find out the fatigue develop during riding for a particular region

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