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Research Article

DESIGN AND DEVELOPMENT OF AN ALL-TERRAIN PURPOSE BICYCLE

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A R T I C L E I N F O

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A B S T R A C T

A bicycle, commonly known as a bike, is a steerable, two-wheeled vehicle that is propelled by the rider's feet. Though there exist various types of bicycles that can used for various activities, each bicycle is specifically built for a specific purpose. In the project of "Design and Development of an all-terrain purpose bicycle", It was decided that the many problems that arise with existing bicycles have to be tackled with a new design and a way to combine all of them has to be found in order to create an ideal bicycle that can be used on all terrains, hence making it an all in one bicycle for all purposes. The deliverables of this project are in the form of primary and secondary research done, ideations and concepts (manual/ digital), 3D model and renderings (digital), Digital simulations for post processing.

INTRODUCTION

A bicycle, also known as a pedal cycle, bike, push-bike, or cycle, is a single-track, pedal-driven, human-powered or motor-powered aided vehicle with two wheels mounted to a frame, one behind the other. They offer a well-liked form of entertainment and have been modified for usage as kids' toys, general exercise equipment, military and law enforcement tools, courier services, bicycle racing, and bicycle stunts. Since the first chain-driven bike was created in 1885, the traditional upright or safety bicycle hasn't altered much in terms of design or configuration. But many elements have been enhanced, particularly with the use of contemporary materials and computer-aided design. These have made it possible for a variety of specialized designs for cycling to proliferate. [1] Though these advancements in the design of bicycles have led to various kinds of bicycles to be made, it hasn't resulted in the ideal bicycle that could be used on all terrains. It only makes sense to have one bicycle that could be used for racing, mountain biking, touring, etc instead of having multiple bicycles for the same. An ideal design with various features and requirements have be decided and implemented into a typical bicycle to make it ready for all terrains.

Background Theory

In recent years, bicycles have gained even more significance. Even though they have long provided us with many benefits, they are now quite important. They provide a more environmentally friendly method of transportation due to the rate at which pollution is increasing in the world. In other words, bicycles don't use any petrol or diesel, which is bad for the environment. Additionally, it does not produce any carbon emissions. Therefore, it is a fantastic option for everyone, especially for those who care about the environment. Given the 150-year history of the bicycle and its patterns of radical change followed by convergence and consolidation, it would be absurd to suggest that the current product signifies the end of the road for innovation in this sector. [2] The late 2000's saw a rise in the development of multi-terrain bicycles that are referred to as hybrid bicycles that were a combination of both a road cycle and mountain bike. This was the first attempt to combine bicycle features to make it tread on smooth tar as well as loose gravel. But after this attempt, there was no other push to combine features of other types of bicycles that could ultimately lead to the emergence of an all-terrain bicycle.

Evolution of Bicycles

While the fundamental frame hasn't changed much in over a century, the introduction of space age materials like titanium and carbon fibre has resulted in bikes that are lighter and more durable than anything the designers of the early iron and wooden versions could have ever envisaged. In order to incorporate design elements that expressly assist one particular type of riding to the exclusion of others, bike styles have also evolved. Because of this specialisation, you can go into any bike store and choose from a variety of bikes depending on where and how you want to ride, including road bikes, hybrids, cruisers, and more. As cycling culture spreads and more of us are concerned with lowering our carbon footprints and being active, more and more of us are stepping out of our automobiles. The majority of us have grown up riding bicycles for recreation, but it is only recently that they have replaced cars as our preferred mode of transportation. These

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technical advancements made it easier and faster for city inhabitants to commute or visit the countryside. Bicycles in particular helped women become much more independent. [3]

Benefits of Bicycles

Regular aerobic exercise has several health advantages. Depending on your riding technique and the state of the local roads, brisk cycling may easily burn 600 calories in an hour. The majority of bike commuters claim to have lost 15 to 20 pounds over their first year of riding without altering their eating routines.

METHODOLOGY

Objective No.	Statement of the Objective	Method/ Methodology	Resources Utilised
1	Literature Study	Reading	Books, Journals, Articles, Theses
2	User Study	Interviews	Cyclist, athletes, common man, etc.
3	Concept Development	Sketching, Form Exploration	Digital modelling
4	Concept Detailing	Digital Rendering	Digital modelling and Rendering
5	3D modelling	Digital modelling	CATIA V5, Keyshot
6	DFMA	Guidelines	Boothroyd Dewherst

Data Collection

When choosing the perfect kind of bicycle for yourself, it is very important to understand that you should know what you are looking for. When you walk into a bike shop, you are probably going to be asked first what type of bicycle you want, be it a road bike, mountain bike, or a hybrid bike. Your decision entirely rests upon your biking needs and personal preferences. Some people look for speed control, some love doing tricks while many others take part in bike races. [4]

Types of Bicycles

- **Road bikes** are best identified by their drop or turned-down handlebars and skinny tires. The downward-curving handlebars are usually super lightweight that help put you in an aerodynamic position.
- **Mountain bikes** are designed with excellent braking systems and shock-absorbing features that can easily handle serious bumps, rocks, dirt trails, roots and ruts. Mountain bikes are meant for dealing with steeper terrain which is why most of them consist of lower gears.
- **Touring bikes** are almost like the traditional road bikes, except with a few tweaks and changes that make them perfect for long-distance bike tours.
- **Folding bikes a**re believed to be excellent travel companions. As the name suggests, they fold super easily and smoothly, allowing them to be able to effortlessly fit on a boat, in the trunk of a car or on a subway.
- **Track bikes** often referred to as "fixies" or Fixed Gear bikes are primarily used for racers and athletes that are training for professional races**.**
- **BMX** is an acronym for Bicycle Motor Cross, primarily because this type of bicycle is a single-speed bike that is raced around short dirt tracks, quite similar in nature to the motor sport.
- **Cruiser bikes** come under the umbrella term of "specialty bikes" that contain very specific end uses and features, setting them apart from other types of bikes.
- **Hybrid bikes** are best described as a mix of road, mountain and touring bike designs, making them more of "do-it-all" kind of bikes that cater to a wide range of uses.
- **Electric bikes** include an electric motor which you can charge by plugging it into a regular outlet.

Global Cycling Statistics

According to a report by the World Health Organization (WHO), cycling is the fourth most popular physical activity in the world, with an estimated 1.3 billion people cycling regularly. The report also found that cycling participation is increasing in many parts of the world, particularly in urban areas where cycling is seen as a sustainable and efficient mode of transportation. In fact, many cities are investing in cycling infrastructure and bike-sharing programs to encourage more people to cycle. Gender and Age demographics of cycling participation varies by gender and age, with men more likely to cycle than women and younger age groups more likely to cycle than older age groups. However, this gap is narrowing in many countries as more women and older adults are taking up cycling. According to a report by Cycling UK, women's cycling participation has increased by 53% since 2013, while participation among people aged 65 and over has increased by 31%. [5]

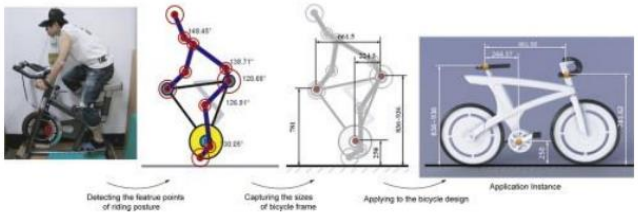
Cycling in India

In terms of bicycles, 50.4 percent of households across India own at least one bicycle. This figure has gone down from 52.1 percent in the survey conducted in 2018. Bengal has the highest percentage of households owning bicycles at 78.9 percent, followed by Uttar Pradesh with 75.6 percent and Odisha (72.5 percent). Globally India tops in those who ride a bicycle at least once a week: Ipsos Global Advisor Cycling Across the World Survey 2022; 9 in 10 urban Indians believe cycling reduces carbon emissions; Cycling infrastructure, safety, determine popularity of riding by markets. At least 2 in 3 urban Indians (67%) claim to be riding a bicycle at least once in a week, which is the highest globally. Followed by China (66%) and Netherlands (65%). While the markets with lowest incidence of riding were Canada (16%) and the UK (19%). [6]

Ergonomics of Bicycle

An ergonomic bike setup aims to keep your centre of gravity over the middle of the bike which is, depending on the design, often right in front of the seat. It is possible to move the seat slightly closer to, or further from, your handle bars. But in most cases, it's best to leave it centred and adjust the height. As a basic guideline, start with the seat close to waist-level. From there, you can go up or down a bit until you find your comfort spot. Seat height may also depend on the type of bike you are riding. Generally, mountain bikes sit a little lower than road bikes. Raising your seat too high leaves you leaning too far forward. This puts extra strain on your hands and wrists as they support more of your body weight. At the same time, you'll also lose some pedal efficiency – your feet have less pedal contact if you are sitting too far up. But sitting too low also has its problems. Not only does it leave you leaning back, it brings your knees up towards your chest mid-pedal, taking

most of the power out of your rotation. If you feel like your foot can barely reach the ground when you are seated, don't worry – that's normal. Ideally, you want your knees coming parallel to the ground at their maximum height and then pushing forward for close to a full leg extension. You should feel that the full rotation is easy, comfortable, and natural. [7]



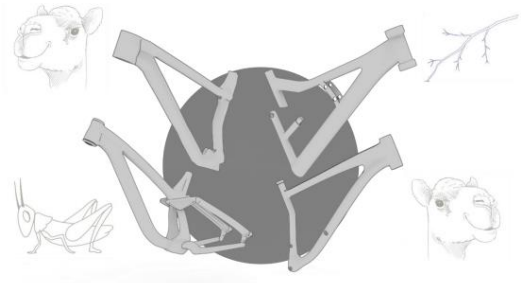
Design and Development

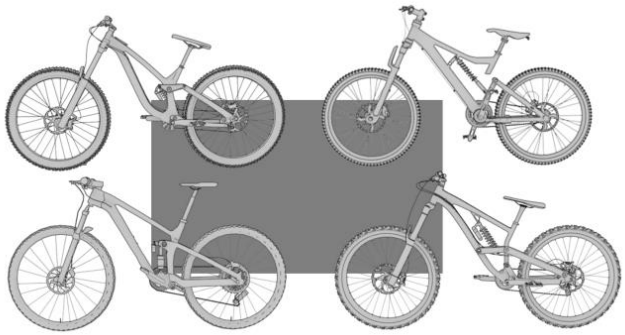
Through popular opinion, from the thorough research, it was found that:

- People prefer using bicycles that can tread on all types of terrain as it becomes easier for them to commute.
- People prefer using bicycles that are lightweight and easy to get on and off.
- People prefer paying no more than 20k for an ideal multi terrain bicycle.
- People prefer bicycles that come with good suspension and wide tires.
- People prefer bicycles with adjustable suspension.
- People would like to see a sleeker design in bicycles.
- People have a liking for bicycles that they require low maintenance.
- People like bicycle parts as modules that can replace and change according to will.

Concept Design and Generation

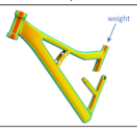
All concepts were made keeping in mind the popular opinion of the summary of our research and in order to get new ideas for an all-terrain bicycle, implementation of various other design elements that can work together to create a new design for an all-terrain bicycle were used.

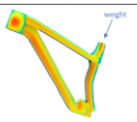


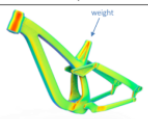


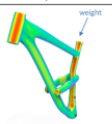
Form Testing of Body Frame

All concept frames had 3D models made of them and were put through various simulations for testing the material and form characteristics. Aspects of wear and tear were taken into consideration having the highest amount of force applied to it being 1000N during testing. The simulations provided information that could help determine which form structure had the best capabilities of withstanding external forces and gave a detailed sheet of its physical and chemical characteristics. The overall performance percentage saw that concept 3 was the best structure for making a bicycle as with the forces applied on it from the seat area and external forces, The yield result showed an overall performance percentage of 96% making it the ideal form structure for an all-terrain bicycle.

Concept 1	Material used: Aluminum (al)	Impact resistance (1000N): 86%
	Frame weight: 4.5kg	Ultimate breaking load: 2800N
	Sheet metal thickness: 0.8mm	Ultimate tensile strength 179 MPa
	Type of welding: TIG	Chemical inertness: 94%
	Weight applied on weld areas: 70kgs	Weather resistance: 90%
	Stress restraint: 78%	Flexibility resistance: 96%
	Strain restraint: 89%	**OVERALL PERFORMANCE: 86%**

Concept 2	Material used: Aluminum (al)	Impact resistance (1000N): 92%
	Frame weight: 4kg	Ultimate breaking load: 3100N
	Sheet metal thickness: 0.8mm	Ultimate tensile strength 199 MPa
	Type of welding: TIG	Chemical inertness: 94%
	Weight applied on weld areas: 70kgs	Weather resistance: 90%
	Stress restraint: 88%	Flexibility resistance: 98%
	Strain restraint: 91%	**OVERALL PERFORMANCE: 93%**

Concept 3	Material used: Aluminum (al)	Impact resistance (1000N): 96%
	Frame weight: 6.5kg	Ultimate breaking load: 3800N
	Sheet metal thickness: 0.8mm	Ultimate tensile strength 239 MPa
	Type of welding: TIG	Chemical inertness: 94%
	Weight applied on weld areas: 70kgs	Weather resistance: 90%
	Stress restraint: 94%	Flexibility resistance: 98%
	Strain restraint: 96%	**OVERALL PERFORMANCE: 96%**

Concept 4	Material used: Aluminum (al)	Impact resistance (1000N): 90%
	Frame weight: 5.5kg	Ultimate breaking load: 3300N
	Sheet metal thickness: 0.8mm	Ultimate tensile strength 218 MPa
	Type of welding: TIG	Chemical inertness: 94%
	Weight applied on weld areas: 70kgs	Weather resistance: 90%
	Stress restraint: 84%	Flexibility resistance: 94%
	Strain restraint: 89%	**OVERALL PERFORMANCE: 91%**

Concept Modelling and Rendering

All parts of the product were design ergonomically and to standard dimensions giving room for adjustability in order to ensure comfort and stability of the product when in use. Each part was also design in such a way that only a single alan key is required to assemble or disassemble the product allowing for easy maintenance and replacement or repair of certain parts. The product was rendered in keyshot with the appropriate materials given for the respective parts and giving it a representative appearance for how it would look like when the prototype was finally made. The colour was also chosen considering to be attractive and to bring out the aesthetics of the form. All the essential components that would be required in a typical bicycle were added to ensure that the bicycle functions normally, however, few additional features were given in order to make the bicycle ready to conquer the all-terrain world.

Features of the All-Terrain Purpose Bicycle

- Light weight body with wheels (10kgs)
- 25mm Telescopic front hydraulic suspension.
- Compressed spring handle bar suspension.
- Combined body frame and swing arm (uni-body)
- Adjustable fluid monoshock suspension.
- Adjustable angled seat for required riding ergonomics.
- Raised handle bar for easy reach.
- 5 speed gear system with quick shifter.
- Dual disk brakes and aluminium brake pads.
- Stable and durable frame inspired from nature.
- Dual finger brake system for easy control.
- Commuter style riding ergonomics for easy rides.
- Single style alan screws used for all module joints.
- Wide pedals for easy grip due to large surface area.
- Easy set chain sprocket to avoid chain from coming off.
- Angled seat to ensure rider ergonomics are maintained.
- Dimensions followed as standard with levels of adjustability.
- Each module can be independently removed in cases or part replacement.

The rider's triangle follows the standard ergonomic design that allows for simple commute design that sees a handle height slightly higher than the seat making its reach much easier and requires very less to no stress on the spine. Moreover, the adjustable features allow us to custom adjust it to our personal preference and comfort making it ideal for ride.

CONCLUSION

The design and development of an all-terrain purpose bicycle looks into the aspect of making the one ideal bicycle that can be used everywhere by everyone. It includes various light components that we tend to find in motorbikes. The inclusion of adjustable suspension makes it easy to use everywhere as we can simply adjust it to suit our comfort on the terrain in which we ride.

The design is also unique that seeks inspiration from nature while maintaining its primary function of supporting the entire bicycle system. Through simulations and testing, using aluminium as the prime material, it was found that the design chosen and made is ideal for an all-terrain bicycle and despite all the features it has, it is relatively as light as a simple road bike with a weight of only 10kgs that makes it very light for a bicycle that can go both on-road as well as off-road.

The project helped uncover many problems with existing bicycles mainly that of being bad ergonomics and high maintenance. The single frame of the design created that incorporates the body frame and swingarm features as one part makes the product much easier to maintain with lesser parts than a standard bicycle. Overall, the all-terrain purpose bicycle makes the only bicycle that a person will ever need for all the purposes they wish to achieve also coming in a price range very affordable by the common man unlike similar existing products. The features and form make it unique to stand out and aesthetically pleasing to everyone.

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