Design and Concept Evaluation of frame for One Wheeled Motorcycle

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***Abstract*— Since, the discovery of wheels in the early times, transportation becomes easier. In recent years rivalry in the automobile market is getting increased day by day with respect to fuel economy especially for the light commercial vehicles. In present scenario, every individual has a two wheeler and they are using this even for reaching for short distances. By this conventional resources like petrol and diesel are consumed more and more. Not only the depletion of resources, it produces more environmental pollution threats. To overcome this issue, people has enforced and encouraged for use of comparatively unconventional energy resources such as electric vehicle. A one wheeled motorcycle is fast growing vehicle for undergoing transportation. In this study, a single wheel self-balancing electrical vehicle is proposed. The concepts were design with free hand sketches and concept evaluation cane be done with the help of Pugh chart selection matrix.**

Index terms – Concept generation ; self-balancing; electrical vehicles; Pugh chart.

I. INTRODUCTION

The objects of functional value to people are created by the product design process. It involves the understanding of materials, approaches, ergonomics, human behavior's and structure. The role of the product designer is to identify the problems in the current design and come out with the solutions that could impress the end user. The application of problem solving approach in design supports to obtain the end results. The problem solving methodology in design consists of the following steps.[1]

- Categorization of the problem
- Collecting the information
- Generation of different solutions
- Assessment of alternative
- Communication of the consequences.

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The definition of the problem is the detailed statement of the problem faced in the existing design of the product. Collecting of information is the gathering of specific and current information regarding the product from papers, patents, collections, handbooks and literatures published by vendors. The generation of another solutions depends on the innovative thinking capability of a designer.[2]

The ability to generate high quality another solution is vital for an effective design. The estimation of alternative solution consists of systematic methods for selecting the best among several designs. Simulation of performance with computer models is finding wide usage. The statement of results involves a written design report details the 3D model dimensions and analysis of the product at the end of the project which should satisfy the need of the customer.

II. STANDARDS FOR ASSESSMENT IN THE EXISTING DESIGN

The existing one wheeled motorcycle's design procedure and performance are deeply evaluated to understand the various constraints associated with it. Generally, in a typical product development process, the product is valued based on a detailed set of design standards. The design standards are framed with regard to cost, functionality, safety, maintenance, robustness, availability, in addition to a specific set of criteria depending upon the product being considered. [3]

A detailed set of criteria for the design of comfortable one wheeled motorcycle is considered and the existing design and performance are evaluated to understand its limitations.

Depending upon the limitations of the existing product for the principles considered new designs are proposed to overcome the restrictions. In this work, the formulated criteria for the comfortable unicycle design and its evaluation mainly based on the driving methods , stability of drive condition, portability, ease of transportation , compactness, material used, tire size, weight, etc.. The formulated set of criteria's which overcome the limitations in the existing design strengthened the need for a new comfortable design.

III. CONCEPTUAL DESIGNS

Conceptual design is the very first stage of design, in which conceptual sketches or solid models are the principal tools and products. The conceptual design stage delivers a description of the proposed system in terms of a set of integrated ideas and concepts about what it should do, behave, and look like, that will be understandable by the users in the manner intended. Figure 1 shows important steps in the conceptual design.

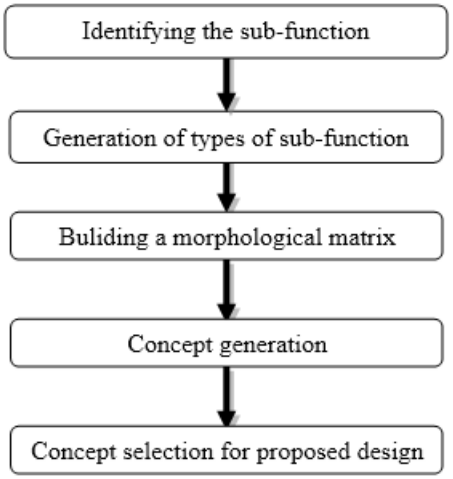


Figure 1: Conceptual design activities [4]

a) Identifying the sub-function –

In this stage, various sub-functions that are needed to accomplish the overall function are identified and generated. Conceptual designs are generated by different ways by using the sub-functions. Sub-functions identified to build a comfortable one wheeled motorcycle are frame section, frame type, joints, links, drive mechanism, handle bar, wheel, suspension and dynamic interface. To accomplish of the overall function of the product the sub-function identified is utilized.

b) Generation of types of sub-function –

The next stage is to develop as several theories as possible for each sub function. To accomplish each sub function a variety of options would be available. The available options for each sub function are then identified as real devices. In the current study the subcomponents needed for the formulated sub-functions like frame shape, drive mechanism, suspension etc. have been determined. The table shows the number of sub components needed for the corresponding sub functions.[5]

c) Morphological matrix –

The Morphological Matrix is a tool for creating options. It provides a well-organized or efficient way to generate a large number of possibilities including many unique or highly unusual options. It contains several rows and columns and resembles like a matrix it's shown in Table no.1 & 2. Each row contains a particular sub function and different methods by which it can be accomplished. It has n*n elements. It is used to build n number of new unicycle design concepts by choosing a particular sub function with its solution to solve a particular design constraint. For example (1, 1) + (2,2) + (3,7) + (4,6) + (5,3) + (6,5) + (7,3) + (8,7) + (9,1) + (10,6), maybe choose as a design concept to solve a particular problem. The first number indicate the sub function type and second number indicate the solution associated with that particular sub function as taken in morphological matrix.[6]

IV. CONCEPT GENERATIONS

The concepts are generated by using pencil drawing as free hand sketches in the conceptual design stage. Hand sketches are more flexible than CAD modelling which are too rigid. In the beginning free hand sketches tell the possible several solution concepts to the identified problem. Some of the five feasible combinations for the good comfortable concepts and their short description of each concept is described below.[7]

A. Concept 1-

It involves a proposed comfortable unicycle design created from the combination and free hand sketching: (1, 5) + (2, 2) + (3, 1) + (4, 5) + (5, 3) + (6, 5) + (7, 1) + (8, 2) + (9, 2) + (10, 3).
Description:
In this concept, steering is connected to the frame with the help of shock absorber. In this design, as suspension is directly connected to the steering system which will cause the stability to decrease and there will be problem while taking a turn. Seat and handle ensures an ergonomic design. However, the disadvantage is less stability and problem no degrees of freedom for steering. This concept is developed with the gear drive mechanism as shown in figure 2.

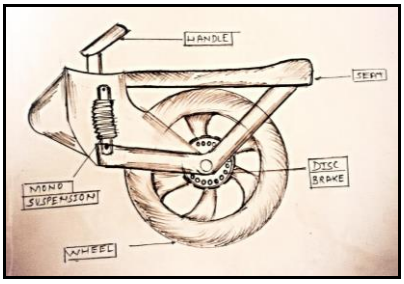
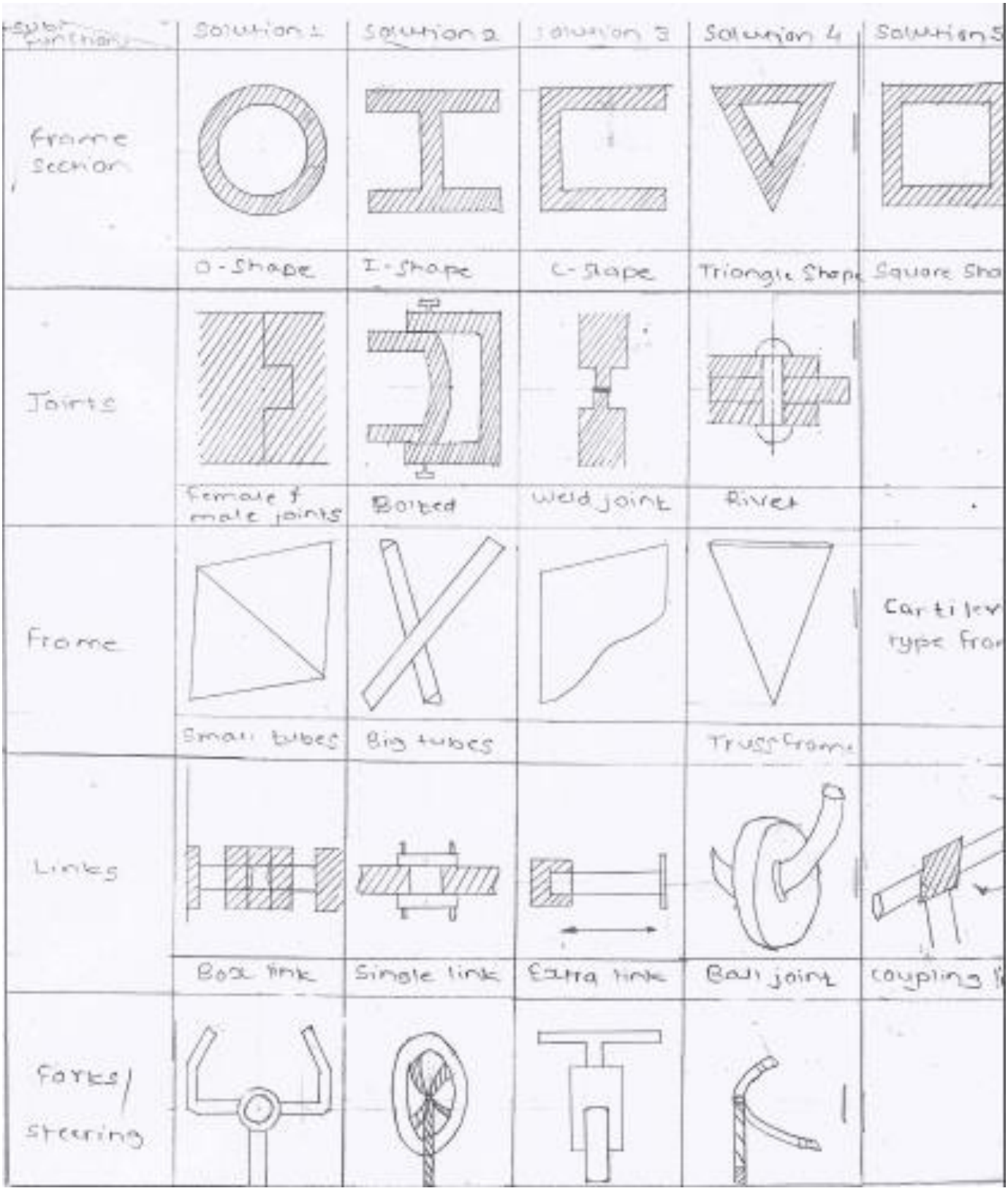
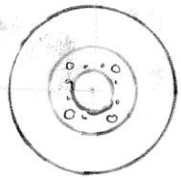
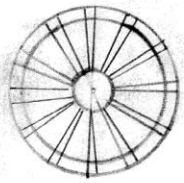
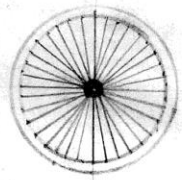
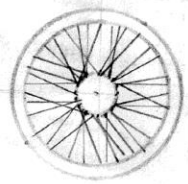
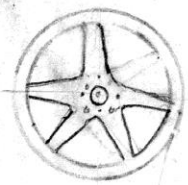
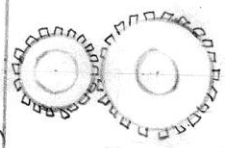
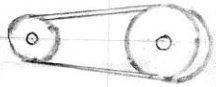
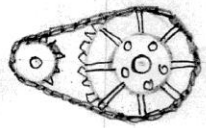
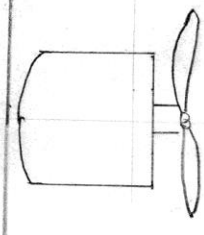
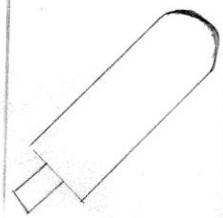
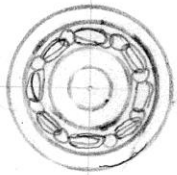
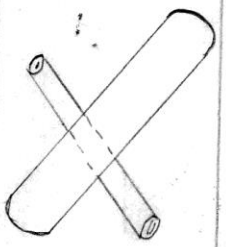
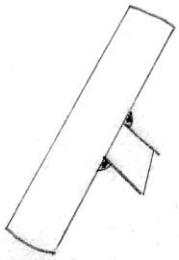
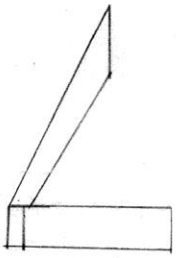
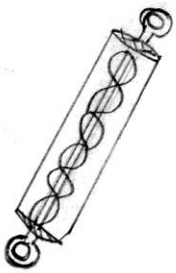


Figure 2: Concept 1

B. Concept 2 -

It involves a suggested unicycle design created from the combination and free hand sketching: (1, 1) + (2, 2) + (3, 2) + (4, 5) + (5, 3) + (6, 5) + (7, 3) + (8, 2) + (9, 1) + (10, 2).
Description:
In this design, frame will not carry heavy loads because of large overhang. Due to drop handlebar rider feel uncomfortable while riding motorcycle for short distance communications. Hydraulic suspension provided at both sides of wheel to reduce vibrations. However the disadvantages are the manufacturing process will be quite hard, manufacturing cost will be high and no steering stability for bike. This concept is developed with the chain drive mechanism as shown in figure 3.


Solution 1
Solution 2
Solution 3
Solution 4
Solution 5
Frame section
O-Shape
I-Shape
C-Shape
Triangle Shape
Square Sha
Joints
Female & male joints
Bolted
Weld joint
Rivet
Frame
Small tubes
Big tubes
Truss frame
Cantilev type fra
Links
Box link
Single link
Extra link
Ball joint
coupling
Forks/ steering

Sub function \ Solutions	Solution 1	Solution 2	Solution 3	Solution 4	Solution 5
Wheel					
	Laminated	Zero cross thin spokes	Zero cross spokes	One cross spokes	Alloy wheel
Drive mechanism					
	Gear drive	Belt drive	chain drive	Motor drive	
Dynamic Interfaces			free wheel		
	Bushes & axles	Ball bearings			
Tube interfaces					
	Drill through	Butt joints			
Suspension Type				Leaf spring type	

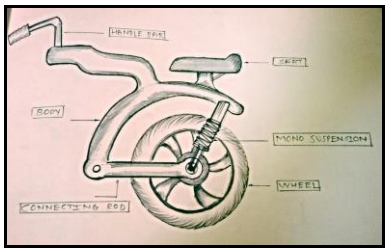


Figure 3: Concept 2

C. Concept 3 -

It involves a suggested unicycle design created from the combination and free hand sketching: (1, 1) + (2, 3) + (3, 2) + (4, 5) + (5, 4) + (6, 5) + (7, 2) + (8, 2) + (9, 3) + (10, 3).

Description:

This concept is designed for casual riding, and has a very comfortable, upright riding position, a large comfortable seat. This can be used for short distance commuting and errands, as long as your route is fairly flat. But this type of frame will not carry heavy loads. The entire unit is difficult to dismantle. Mono suspension provided below the seat structures to reduce the vibrations. Belt drive mechanism used in this concept as shown in figure 4.

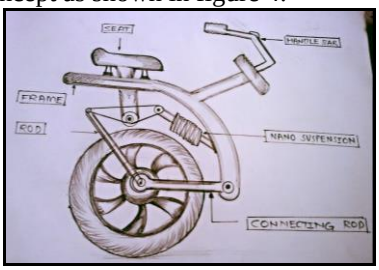


Figure 4: Concept 3

D. Concept 4 -

It involves a proposed comfortable unicycle design created from the combination and free hand sketching: (1, 1) + (2, 2) + (3, 2) + (4, 5) + (5, 4) + (6, 5) + (7, 3) + (8, 2) + (9, 2) + (10, 2).

Description:

Large, padded and adjustable seats and upright handlebars enhances the customer comfort is included in this design. They are ideal for paved or unpaved bike trails, but are not suitable for rough mountain bike trails. Hydraulic suspension provided at both sides of wheel to reduce vibrations. The advantage of this design is ease of assembly and serviceability. This concept is developed with the chain drive mechanism as shown in figure 5.

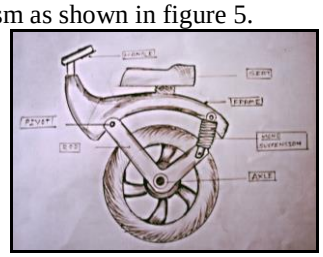


Figure 5: Concept 4

E. Concept 5-

It involves a proposed comfortable unicycle design created from the combination and free hand sketching: (1, 1) + (2, 2) + (3, 5) + (4, 5) + (5, 1) + (6, 5) + (7, 5) + (8, 2) + (9, 1) + (10, 3).

Description:

In this concept design there is cantilever type of chassis. Chassis is hanging at steering column end. While designing this type chassis designer has main task to make to stiffer so that it can carry higher loads. This design is preferred for people who want light, high-performance chassis, but don't like the drop-handlebar riding position. There are large, padded and adjustable seats and upright handlebars provide a comfortable riding position, and are best for casual riding, short-distance commuting, and errands around town. The design reduces the use of fasteners at the Centre of the structure a synchronous belt drive mechanism is used. The entire unit can be easily dismantled. Mono-suspension is provided under the seat to reduce the vibrations as shown in figure 6.

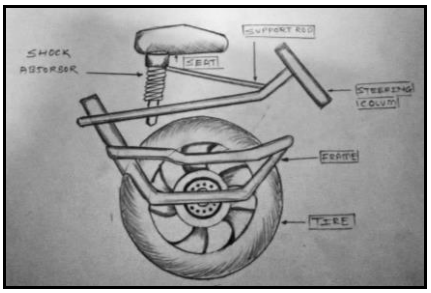


Figure 6: Concept 5

V. CONCEPT EVALUATION AND PROCESS

Morphological chart may provide a lot of concepts to the problem, but not all of these solutions are realistic or able to be worked effectively. The word evaluation at this point means both assessment and choice making regarding the ideas generated in the concept generation stage.

At this stage, the designer begins to limit the possible designs based on ergonomics, aesthetics, manufacturability, cost and other aspects which are relevant to the problem[8].

<u>Pugh Chart</u>

The table 2 shows Pugh chart that has been developed for a one wheeled motorcycle. The criteria chosen for one wheeled motorcycle is based on aesthetics, ergonomics, cost of product, and the basic features needed for the product like ease of assembly, ease of manufacturing, portability, etc.

A Pugh chart is a concept selection tool using the minimum evaluation scale (-, +, s). The design criteria are listed in the left hand side of the table (column wise). The concepts or ideas at the top of the table (row wise). The datum is the reference (may be competitor product) or our own product with a better performance (or) features.

Concepts	**Combination matrix for Conceptual Sketches**
Conceptual Sketch 1	(1, 5) + (2, 2) + (3, 1) + (4, 5) + (5, 3) + (6, 5) + (7, 1) + (8, 2) + (9, 2) + (10, 3)
Conceptual Sketch 2	(1, 1) + (2, 2) + (3, 2) + (4, 5) + (5, 3) + (6, 5) + (7, 3) + (8, 2) + (9, 1) + (10, 2)
Conceptual Sketch 3	(1, 1) + (2, 3) + (3, 2) + (4, 5) + (5, 4) + (6, 5) + (7, 2) + (8, 2) + (9, 3) + (10, 3)
Conceptual Sketch 4	(1, 1) + (2, 2) + (3, 2) + (4, 5) + (5, 4) + (6, 5) + (7, 3) + (8, 2) + (9, 2) + (10, 2)
Conceptual Sketch 5	(1, 1) + (2, 2) + (3, 5) + (4, 5) + (5, 1) + (6, 5) + (7, 5) + (8, 2) + (9, 1) + (10, 3)

Table 1- Combination matrix for conceptual matrix [4]

Pugh Selection Chart						
Criteria	**Datum**	**Concept**				
		1	**2**	**3**	**4**	**5**
Criteria 1 : Ease of Maintenance	0	-	+	-	+	+
Criteria 2 : Affordable Cost	0	-	-	-	+	+
Criteria 3 : Ease of Manufacturing	0	+	-	+	+	+
Criteria 4 : Easy to use	0	-	-	-	-	+
Criteria 5 : Joints and Links	0	-	+	-	-	-
Criteria 6 : Good Portability	0	-	-	+	+	+
Criteria 7 : Good Ergonomics	0	+	-	+	+	+
Criteria 8 : Ease of Adjustability	0	-	+	-	-	+
Criteria 9 : Good Speed	0	-	-	+	-	-
Criteria 10 : Good Aesthetics	0	+	-	+	+	+
S-		- 6	- 7	- 5	- 4	- 2
S+		+ 4	+ 3	+ 5	+ 6	+ 8
S		- 2	- 4	0	+ 2	+ 6
Selected Sketch		Selected Sketch 5				

Table 2- Concept Evaluation and Selection using Pugh Chart [9]

The scale (-, +, s) is used for rating different concepts against criteria. "-"indicates worst design than datum. "+" indicates better design than datum. "S" or "0" indicates same as the datum. Σ+ve, Σ –ve and Σ avg is done for each and every concept. The one with the minimum number of "-"points, highest number of "+" points and the better average score is selected as the best design. [10]

The concept evaluation and selection using Pugh chart is shown in Table 2. For example the "-ve" sign for the concept 1 against the criteria, ease of maintainability indicates that it less easy than the data obtainable model. Likewise the evaluation should be performed for several other design concepts with respect to the principles deliberated. After the rating is done for five possible combinations or concept, it is determined that concept 5 has the highest value of points as "5" when compared with other design approaches. This concept 5 is observed as the best model to implement the comfortable unicycle.

VI. 3D MODEL GENERATION AND PROTO MAKING

After finalizing concept CAD model is generated in PTC Creo 2.0 for further work as shown in figure 7.

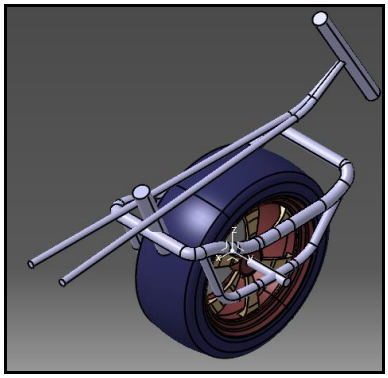


Figure 7: CAD model

After CAD model generation proto making is done with the help of PVC pipes as shown in figure 8.

Figure 8: Prototype model

VII. CONCLUSION

The concepts are generated focusing on the requirements of product design. The generated concepts are evaluated using different criteria's. The final concept assures to be a cost effective design, satisfying the customer in terms of stability and safety. The CAD model generation is done using PTC Creo 2.0. It has provided the lower assessment score thus suggesting that the design is comfortable and effective than the remaining design.

VIII. FUTURE SCOPE

In future, modelling details can be done by material selection, analysis & optimization. Once the design is optimized, the proposed design has to be fabricated.

ACKNOWLEDGMENT

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