Chapter VII1

8. Conclusion

8.1. General Overview

Previous chapters conclude that the preliminary design of Power Transmission System of the first embodiment of the pedal car is feasible because it operates 15Km/hr in level roads and 8km/hr in gradients. Strength and rigidity of the first embodiment is far more superior to other tricycles. Appearance is attractive and fashionable. Most significant difference in this design compared to other pedalling tricycles is elimination of long chains and incorporating pedal link for pedalling. Pedalling provides extra value to the rider since it provides physical exercise while riding.

Limitation applicable to this project is provision of necessary human power for acceleration of vehicle in gradients. Sri Lankan population can provide 0.23 Horse Power in pedalling is one of the hypotheses and which is true and in some occasions this value varies from 0.23 hp to 0.4 hp as shown in figure 7.2 depending on the person who pedals. Unlike engine characteristics, application of human characteristics is limited. Therefore Ergonomics considerations, minimizing weight of the vehicle, and alternative mechanisms for increasing tractive power and turn down ratio are considered for further improvement to the first embodiment. Tilting of first embodiment in sharp turn is to be considered for further improvements. Finally recommendations and further research areas are also identified in this chapter.

8.2. Achievements and Positive Aspects

One of the major aspects of first embodiment is to have an ergonomically designed and fabricated product ensuring easy posture and free and comfortable pedalling than in bicycles and other tricycles while maintaining stability in riding. These aspects are very critical with respect to pedalling efficiency, strength and rigidity of the structure and the safety of the rider as well. In addition to the above aesthetic aspects, fashionable appearance is also critical in order to popularize the product among target group. Trouble free, environmentally friendly operation, easy maintenance, and finally affordable price are the other importance aspects of this project.

8.2.1. Configuration of the first Embodiment (CLWB) and Ergonomically Designed Seat

First embodiment was fabricated based on Compact Long Wheel Base (CLWB), two wheel in front configuration with recumbent position. These CLWB (47" to 60") types are most suitable for urban environment and sport and recreational purposes. Therefore configuration of first embodiment is matching with the user needs. On a recumbent seat is chair-shaped, and since the pedals are out in front it is arranged in more ergonomics way. Recumbents have better pedalling efficiency, much better comfort for extended riding, and better aerodynamics. Basic user-friendly ergonomics include a moderate seat height of around 20 or so inches off the ground, with pedals mounted noticeably lower. Since the seat height of first embodiment is nearly 22 inches from the ground and all the above mentioned factors are incorporated in this design this project has achieved its ergonomics targets.

8.2.2. Stability while Riding

Motor cycles and pedal bicycles are not balanced designs and they are pronged to cause unsafe conditions while driving because rider has to apply extra efforts to balance the vehicle. But first embodiment has three wheels and rider is not subjected to unsafe conditions as in the above case. Hence rider does not want to concentrate on balancing the vehicle and free to concentrate on pedalling.

8.2.3. Pedalling Efficiency

Pedalling efficiency is an integral part of recumbent. Compact Long Wheel Base configuration ensures the free leg movement. Since the pedals height is lower than the seat in the first embodiment neck fatigue would not cause to the rider. This improves the pedalling efficiency in one way.

8.2.4. Easy Manufacturability and Maintainability of Driving Mechanism

All the types of long wheel based recumbent in the world so far used, have adopted long chains for power transmission systems in pedal tricycles and bicycles. These chains are double the length of the chain used in the first embodiment. Main feature of the first embodiment is this short chain and pedal link. Therefore operation is trouble free and maintenance is easy. Most of the parts in the driving mechanism, pedal, drive chain, gears are standard parts and they are cheap. Assembling fixing and aligning the parts of the driving mechanism is also easy.

8.2.5. Brake and Steering System

Brake system is reliable because drum brakes were used in the first embodiment. Steering system of the first embodiment is a combination of recumbent steering. Over-seat steering (OSS) is one of the recumbent steering and it is the more common, normal, user-friendly, and performance-oriented one. First embodiment was made using OSS and integrated some of the features of the other recumbent steering, Under Seat Steering (USS). Fork modifications and steering linkages, and rod end bearings etc are those features incorporated into the first embodiment in order to ensure reliability of brake and steering unit as a whole

8.2.6. Environmentally friendly, Fashionable Appearance and Inherent Values in Pedalling

First Embodiment provides exercise to the rider without wasting his time and money for exercise machines or going to gymnasiums. Environmental pollution is eliminated since human power is used for power generation to propel the vehicle while not contributing to noise pollution. Usage of small tyres resulted less frictional resistance and good appearance. Configuration of the first embodiment and standard parts used for steering and other components finally gave a fashionable appearance.

8.2.7. Affordable Price

Cost of the first embodiment is around Rs. 17,850.00 without hood. Since the parts used are standard and further improvements are possible the total cost could be minimized to Rs.20, 000.00

8.3. Problems En-countered and Limitations of the Study.

Problems encountered	Limitations
1. Bending of pipes for the frame of the first embodiment was difficult because they were heavy and thick. 2. Actual weight of the first embodiment is 13Kg more than the estimated weight. 3. Since the structure was heavier than estimated, normal brakes used in bicycles were not adequate for braking. . Standard drum brakes of "chally" motor Cycles were used for front two wheels. These drum brakes are not freely available in the market matching exact size hub to suit the selected front wheel spokes and the axle. Therefore new hub was turned out as shown in Fig 5.9,5.10, & 5.11 and welded to the drum. After that spokes were cut to wheel size and re assembled.	1. Maximum weight of the first embodiment was estimated for 100kg with the rider but it was 113Kg after fabrication because heavy and thick gauge pipes were used for first embodiment in order to ensure strength and rigidity of the system. 2. Due to time constraints computer aided analysis was not done for the final design of the frame before fabrication. Preliminary design of the frame was used for fabrications. 3. Because of this heavy gauge pipes and components of brake and steering system resistance to acceleration in gradients is increased and critically affected since the actual weight of the vehicle is more than the estimated weight.

Problems encountered	**Limitations**
4. Since the camber of the two fronts wheels are not perfect front wheels inclined outwards when pedalling. Fork modifications and steering linkages, and rod end bearings etc are used to rectify. 5. Pedalling was difficult in gradients to propel the Pedal car in testing stage.	**4.** Human power that can be applied for pedalling in Sri Lanka population is 0.23 Horse Power. This value may be varied between .23 hp to .4hp. maximum speed that can be achieved is 8 Km/h speed in gradients.
6. First embodiment is tend to tilt mostly in sharp corners because centre of gravity was unable to set while fabrication as estimated.	5. Though the centre of gravity to be fixed 15% of the wheel base from the front axle for elimination of tilting. It was unable to set as estimated because seat position and height was unable to adjustment in the fabrication stage due to time constraints.

8.4. Recommendations

Problems	Recommendations
1. Minimizing the weight of the first embodiment. See (Appendix D1) (Appendix C1)	1. After analyzing the frame design by finite element method found that the deflection is unaccountable. Therefore Lighter aluminium alloy material used in bicycles, **frame Ni-Si brazed multi gauge crmo, aluminium b-b extension**, can be used for frame and weight of the frame can be minimized by about 40%. 2. Turn out parts used in brake and steering system are also heavy and contributed resistance to acceleration. These parts also can be replaced by optimization of the design, parts reselection or re-design. 3. Total weight of the first embodiment 48 Kg can be minimized by about 25% by implementing above two suggestions.
2. Minimizing the Tilting at sharp turns.	1. Seat should be shifted towards the front wheels, to be fixed at 15% of the wheel base. 2. Drive pedal links and mountings also to be shifted proportionately towards front. 3. Mountings of the Pedals to be lowered as far as possible. 4. Seat should be lowered by 3"- 5". for user friendly recumbent and place much of the rider's weight on their bottom. 5. Frame configuration, frame height also to be minimized in order to lower the pedal mountings as well as to place much of the rider's weight on their bottom.

Problems	Recommendations
3. Pedalling and acceleration of the vehicle was difficult in gradients.	1. Pedalling was difficult in gradients due to limitation of human power, 0.23 horse power. Minimizing resistance to motion, minimizing weight of the vehicle, is one of the solutions as suggested above. 2. Efficiency of pedalling can be further improved by replacing bushes used in pedal mounting by wear resistance sleeve with regular oiling or with sealed roller bearings. 3. Applying extra power input; incorporating mechanism to the power transmission system, hand operated handle coupled to housing of the pedal mounting similar to "Orbitrack" exercise machine or coupling hand operated lever to sprocket wheel.
4. Improvements to the power transmission system	4. Introducing mechanisms for increasing current speed ratio by two to three folds could automatically achieve tractive force by two to three folds for acceleration. The following alternatives may be introduced to the next embodiments. ❖ Introducing rack and pinion gear mechanism for power transmission system with a drive shaft. ❖ Introducing cable replacing chain from the power transmission system with a clutch mechanism.

Problems	Recommendations
5.Construction of Body of the pedal car. Due to time constraints it was unable to construct the covering for rain, heat and dust.	5. Body of the first embodiment is to be in light weight protecting rider from heat, rain, and dust with a clear vision for riding. Critical area in body design should address the aerodynamic resistance, shape of the front side. Front side cross sectional area should be minimized. 1. Fiberglas is one of the lighter materials available locally for body construction. 2. Weight could be further minimized by covering the body by weather proof clothing materials.

8.5. Further Studies

8.5.1 Application of Optimum Human Power Against Pedal Height for Compact Long Wheel Base Recumbent in Sri Lanka

Critical area of power transmission system is the maximum power at several different conditions and comfort of the rider. Previous studies on bicycles used a mathematical model to evaluate, crank length, seat tube angle, seat height, and foot position on the "cost" of pedalling at 200 watts. This essentially means the "efficiency" which examines how to produce that much power with the least wasted effort. Therefore this study relates to ergonomics consideration in combination with power transmission system design. The study on bicycle concluded that the optimum crank length (least cost at 200W) for an average size rider is 140mm. It did conclude that the optimum length varies with rider size.

In this research study, first embodiment, achieve 8 Km/h in gradients at power in put of 205W and in level roads 18Km/h at 180W according to the governing equations used and calculations as shown in Tables 7.1 and Table 7.4. Since these values are closer to actual speeds of the first embodiments Power applied by body weight of the rider in bicycles is look similar in the case of gradient(Appendix D1) in first embodiment and rider has capability to apply more power in order to increase the speed in level roads. Therefore it is important to study about maximum power application without waste with efficient and ergonomics way in relation to pedal height, seat angle, foot position and crank length after implementation of the above recommendations 1,2,3 ,and 5. By doing this study final design could be analyzed and refined it for further improvements.

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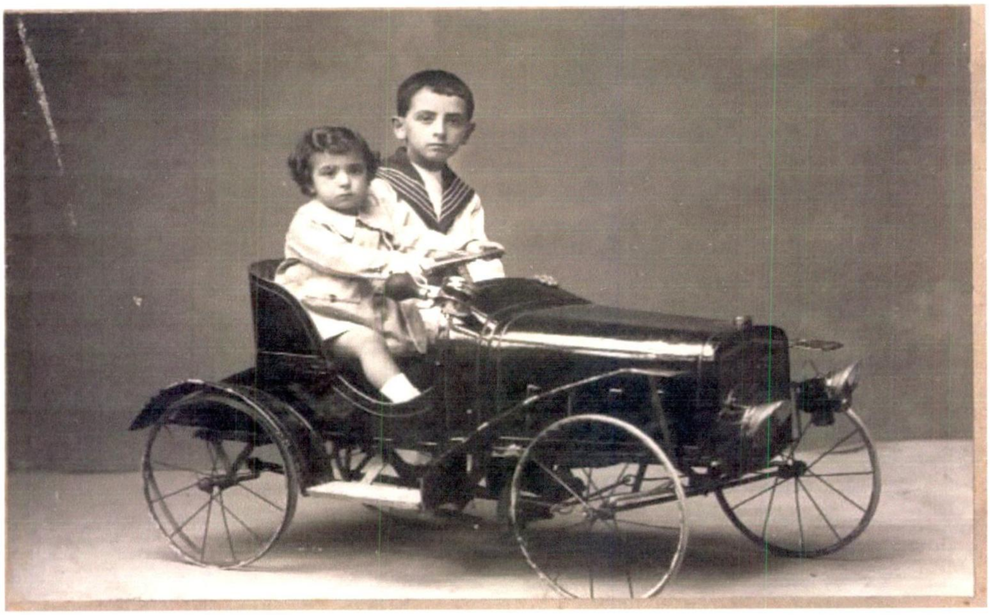
Appendix A1

Eras of Invention of Auotomobiles



"http://en.wikipedia.org/wiki/History_of_the_automobile"

Appendix A2

First patented Benz automobile of 1885

1895 Benz Velo - introduced ten years after the first patented Benz automobile of 1885[2]

[2] History of the automobile - Wikipedia, the free encyclopedia.htm

Appendix B1

Velomobile

From Wikipedia, the free encyclopedia

Jump to: navigation, search

Alleweder Velomobile

A **velomobile** or **bicycle car** is a human-powered vehicle, fully enclosed for protection from weather and possibly from collisions. They are virtually always single-passenger vehicles. They are derived from bicycles and tricycles, with the addition of a full fairing (aerodynamic shell).

Appendix C1

Calculation of Power required for Acceleration in Gradients When Weight of the first embodiment is reduced to 35 Kg then total weight with the Rider M=100Kg

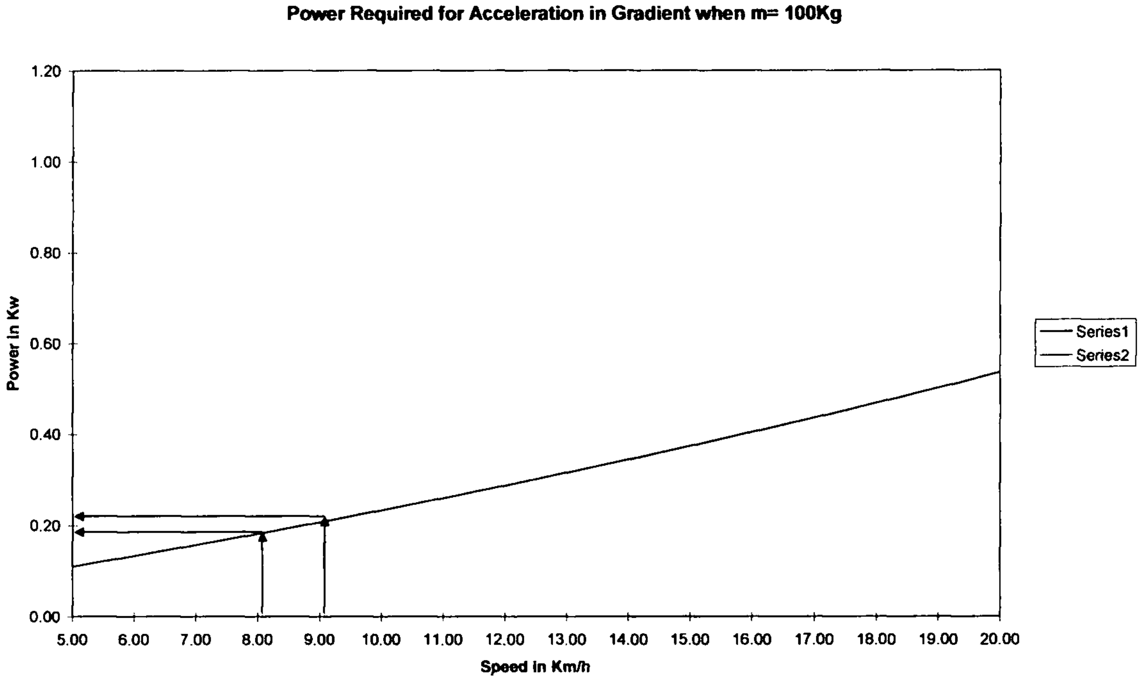
Speed of the vehicle Km/hr	Rolling Resistance=Rr = 0.0112 mg + 0.00006 mg. V	Gradient Resistance in gradients=Rg = WG = mgsin ø	Air Resistance=Ra = KaA.V^2	Tractive Resistance =RT = Rr + Ra + Rg= = 0.0112 mg + 0.0006mgV + 0.02688AV^2 + mg G	Power required or demand power=P (demand) = RT x V x 1000 / ηtx 3600 Kw	Power Required in horsepower
5.00	12.75	55.43	0.29	63.32	0.11	0.15
6.00	12.81	55.43	0.41	64.05	0.13	0.18
7.00	12.88	55.43	0.56	64.82	0.16	0.21
8.00	12.95	55.43	0.74	65.61	0.18	0.24
9.00	13.01	55.43	0.93	66.42	0.21	0.28
10.00	13.08	55.43	1.15	67.27	0.23	0.31
11.00	13.15	55.43	1.39	68.14	0.26	0.35
12.00	13.21	55.43	1.66	69.04	0.29	0.39
13.00	13.28	55.43	1.94	69.96	0.32	0.42
14.00	13.35	55.43	2.25	70.91	0.34	0.46
15.00	13.41	55.43	2.59	71.89	0.37	0.50
16.00	13.48	55.43	2.94	72.90	0.40	0.54
17.00	13.55	55.43	3.32	73.93	0.44	0.58
18.00	13.61	55.43	3.73	74.99	0.47	0.63
19.00	13.68	55.43	4.15	76.07	0.50	0.67
20.00	13.75	55.43	4.60	77.19	0.54	0.72

Where , m= 113Kg, G= 9.81cm/sec² Ra= Air resistance

RT = Ra+RG+Rr RT= Tractive Resistance

Appendix D1

Power required for acceleration in gradients at different speeds when M=100Kg.



Appendix E1

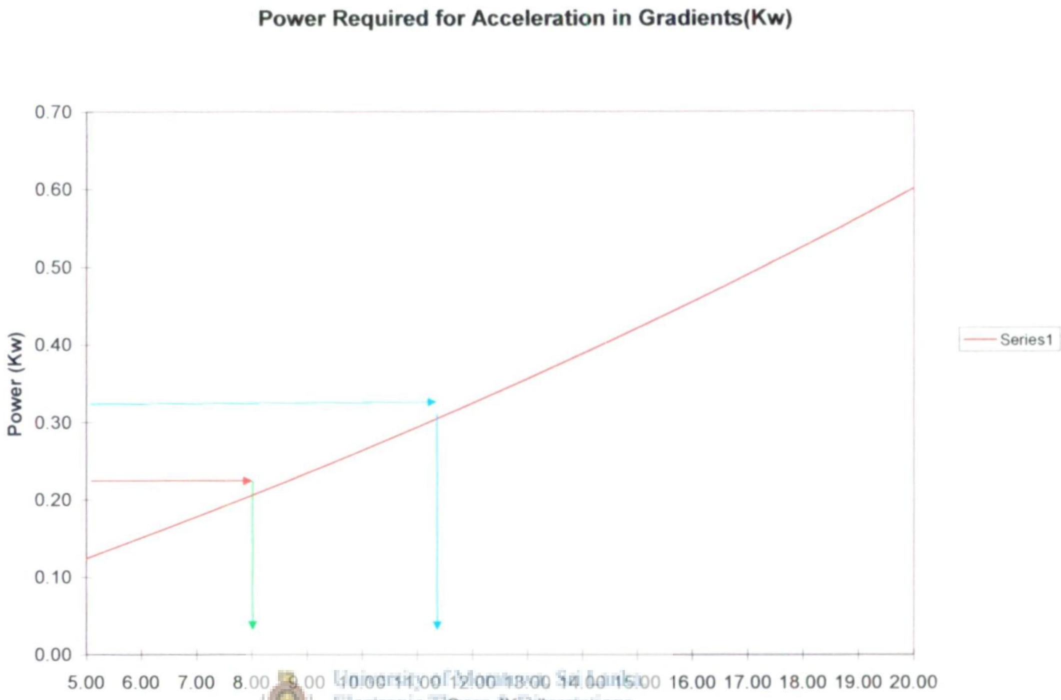
Calculation of Power required for Acceleration in Level Roads
When Weight of the first embodiment is reduced to 35 Kg then totalweight with the Rider M=100Kg

Speed of the vehicle Km/hr	Rolling Resistance= R_r = 0.0112 mg + 0.00006 mg. V	Air Resistance =Ra = KaA.V^2	Tractive Resistance = 0.0112 mg + 0.0006mgV + 0.02688AV^2	Power required or demand power=P (demand) = R_T x V / ηix 3600 Kw	Power Required in horsepower
5.00	11.28	0.29	14.27	0.02	0.03
6.00	11.34	0.42	15.00	0.03	0.04
7.00	11.40	0.57	15.77	0.04	0.05
8.00	11.46	0.75	16.56	0.05	0.06
9.00	11.52	0.95	17.37	0.05	0.07
10.00	11.58	1.17	18.22	0.06	0.08
11.00	11.63	1.42	19.09	0.07	0.10
12.00	11.69	1.68	19.99	0.08	0.11
13.00	11.75	1.98	20.91	0.09	0.13
14.00	11.81	2.29	21.86	0.11	0.14
15.00	11.87	2.63	22.84	0.12	0.16
16.00	11.93	3.00	23.85	0.13	0.18
17.00	11.99	3.38	24.88	0.15	0.20
18.00	12.05	3.79	25.94	0.16	0.22
19.00	12.11	4.22	27.02	0.18	0.24
20.00	12.16	4.68	28.14	0.20	0.26
21.00	12.22	5.16	29.27	0.21	0.29
22.00	12.28	5.66	30.44	0.23	0.31
23.00	12.34	6.19	31.63	0.25	0.34
24.00	12.40	6.74	32.86	0.27	0.37
25.00	12.46	7.31	34.10	0.30	0.40
26.00	12.52	7.91	35.38	0.32	0.43
27.00	12.58	8.53	36.68	0.34	0.46
28.00	12.64	9.17	38.00	0.37	0.50
29.00	12.69	9.84	39.36	0.40	0.53
30.00	12.75	10.53	40.74	0.42	0.57

Where , m= 113Kg, G= 9.81cm/sec² Ra= Air resistance in N
RT = Tractive resistance in N
RT = Ra+RG+Rr in N

Appendix F1

Power required for acceleration on level roads at different speeds when M=100Kg



Appendix G1

Body shape recommended for pedal car