UNIVERSITY OF GLASGOW

ENG2016: Bike Project

GROUP 23

Ivan Mihajlovic	2239242
William Ely	2292204
Qiyu Zhang	2295435
Ewan Walker	2235937
Eduard Fiedler	2248902

Abstract

The purpose of this project is to design an electric bicycle for 55+-year-old men. The goal is to provide insight on the thought process and decision making behind the final design, and how it will be implemented into the current market. This has been done by examining the growing market of electric bikes, and applying sufficient research, in order to construct a realistic bicycle. After analysing multiple different concepts, it was concluded that a menŠs Dutch style bike was the ideal design as it allowed a stylish, and comfortable means of commute, in comparison to alternatives.

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1 Introduction

With a growing interest in battery powered transportation devices, the electric bicycle has experienced a worldwide, rapid growth in popularity since 1998 (Weinert, Burke, & Wei, 2007). However, many companies try to sell their product as an athletic alternative, this caters towards young to middle-aged adults (20-40 years old), and neglects the older population.

The aim is to design an e-bike that accommodates an older audience by reducing effort, emphasising ergonomics, and improving the quality of their commute. The final product is targeted towards a male market, above the age of 55, and will provide these characteristics in an exceptional manner.

This report will convey the emulation of a typical design process, the means used to conduct decisions for the final design, and its implementation into the current market.

2 Project Planning

In order to remain organised, a Gantt chart was formulated. The Gantt chart allowed a visualisation of work allocations for the various topics that were required to complete the project.

2.1 Initial Work Allocations

Table 1: Initial Gantt chart

<table>
<tr><th>Task</th><th>W1</th><th>W2</th><th>W3</th><th>W4</th><th>W5</th><th>W6</th><th>W7</th><th>W8</th><th>W9</th><th>W10</th><th>W11</th></tr>
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In terms of initial work distribution, the complexity of each topic was allocated between the group members based on: background, and abilities. This required the distribution of the CAD work amongst 3 people, as it was speculated to take longer. Furthermore, in the initial stages group work was emphasised to integrate individual concepts, and weekly meetings were scheduled in order to remain on the same page.

2.2 Final Work Allocations

As progress was made with the project, initial roles couldn't be maintained due to different individual schedules. Additionally, by further expanding on the generalised topics in the previous chart, the work had to be allocated differently. This resulted in the following work distribution in order to complete the project on time.

Table 2: Final Gantt chart

<table>
<tr><th>Task</th><th>W1</th><th>W2</th><th>W3</th><th>W4</th><th>W5</th><th>W6</th><th>W7</th><th>W8</th><th>W9</th><th>W10</th><th>W11</th></tr>
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3 Product Design Specification (User Requirements)

4 Biomechanics

5 Current Market Analysis

6 Conceptual Design

6.1 Initial Sketches

6.2 Morphological Analysis

7 Quality Function Deployment

In order to meet customer demands, research and initial product specifications are combined to form the House of Quality. The aim is to produce a customer driven product which will fulfil key demands, by translating user requirements into engineering requirements. Then, by comparing the individual aspects, the importance can be visualised and securely compromised if they are deemed unimportant to the design.

7.1 Engineering Specifications

Table 3: Translation of user requirements

Category	User Requirements	Engineering Specifications	Ref
Performance	Bike parts will last for a long time	Fatigue Limit Cycles	1
	Adequate gearing for a city environment	Number of Gears	2
	Mobility at moderate speeds	Turning radius at 20km/h	3
	Temperature resistant	Melting point of Material	4
	Corrosion resistant	Based on material selection	5
	Luggage space	Amount of suitcases supported	6
	High acceleration from rest	Effort required for acceleration	7
	Low-effort for commute	Effort required for distance	8
	Supports the weight of the rider	Material yield strength	9
	Good braking	Braking distance from max speed	10
	Low centre of gravity	Height of C.o.G. above ground	11
Battery	High battery capacity/battery lifespan	Battery capacity	12
	Battery assists up to specified speed	Input choked at certain speed	13
	Battery recharges quickly	Recharge cycle time (full)	14
	Battery supports significant power	Work input	15
Suspension	No deformations due to vibrations	Material yield strength	16
	Remains steady at high speeds	Structural vibrations	17
	Smooth ride	Spring stiffness	18
Ergonomics	Comfortable riding position	Amount of satisfied people	19
	Height adjustable seat and handlebars	Range of adjustment	20
	Easy to assemble	Assembly time	21
	Easy to maintain	Amount of tools required	22
	Easy to carry	Overall weight of bicycle	23

When translating user requirements to engineering specifications, various methods of testing and measuring are used to describe them. In terms of performance, properties of the general structure of the bike, and its functionality are considered. Furthermore for the battery and the suspension, these characteristics were considered outside of the performance, as they are aspects that must be well defined for the end design of the bike. Lastly, requirements categorised as ergonomics, are quantified in terms of ease of use and comfort.

7.2 Analysis

To form the House of Quality, the following investigations were made to find relationships between the requirements:

- What vs. How? (User requirements vs. Engineering specifications)
- How vs. How? (Engineering specifications vs. Engineering specifications)

- Who vs. What? (Potential buyers vs. User requirements)
- Now vs. What? (Similar products on the market vs. User requirements)
- How much? (What are the feasible targets in terms of engineering specifications)

In the first phase of analysis, User requirements and Engineering specifications are inspected for relationships.

Table 4: House of Quality

Who					How																							Now (Greenedge CS2 -- x; Trek Lift+ Men -- o; Dutch Step-through (our design) -- v)				
Sales person	Recreational rider	Target commuter	What	E-Bike for 55+ year old men	Fatigue Limit Cycles	Number of Gears	Turning radius at 20km/h	Melting point of Material	Based on material selection	Amount of suitcases supported	Effort required for acceleration	Effort required for distance	Material yield strength	Braking distance from max speed	Height of C.o.G. above ground	Battery capacity	Input choked at certain speed	Recharge cycle time (full)	Work input	Material yield strength	Structural vibrations	Spring stiffness	Amount of satisfied people	Range of adjustment	Assembly time	Amount of tools required	Overall weight of bicycle	1	2	3	4	5
				Direction of Improvement	↑	↑	↓	↑		↑	↓	↓	↑	↓	↓	↑	↑	↓	↑	↑	↓	↓	↑	↑	↓	↓	↓					
				Units	#	#	m	K	Type	#	%	%	Pa	m	m	Ah	km/h	h	W	Pa	Hz	%	#	m	s	#	kg					
5	3	6	Performance	Bike parts will last for a long time																								x			v	o
5	4	5	Performance	Adequate gearing for a city environment																										x	ov	
4	5	5	Performance	Mobility at moderate speeds																										x	o	v
4	3	4	Performance	Temperature resistant																											xov	
4	3	4	Performance	Corrosion resistant																												xov
4	3	4	Performance	Luggage space																								xo		v		
5	4	4	Performance	High acceleration from rest																									x	v	o	
3	3	5	Performance	Low-effort for commute																										xv	o	
4	4	4	Performance	Supports the weight of the rider																											x	ov
4	4	5	Performance	Good braking																										x	ov	
5	5	5	Performance	Low centre of gravity																									x			ov
5	5	6	Battery	High battery capacity/battery lifespan																									x		v	o
4	4	4	Battery	Battery assists up to specified speed																										xv	o	
5	5	5	Battery	Battery recharges quickly																										xv	o	
4	5	6	Battery	Battery supports significant power																								x		ov		
4	4	5	Suspension	No deformations due to vibartions																									x		v	o
4	4	4	Suspension	Remains steady at high speeds																									x	v	o	
4	5	4	Suspension	Smooth ride																									o	x	v	
5	6	6	Ergonomics	Comfortable riding position																									xo			v
6	6	2	Ergonomics	Height adjustable seat and handlebars																										x	ov	
4	6	2	Ergonomics	Easy to assemble																										ov		x
4	5	3	Ergonomics	Easy to maintain																								x	ov			
4	5	2	Ergonomics	Easy to carry																								x	v		o	

8 Detailed Design

8.1 Components

8.2 Material Selection

8.3 Calculations

8.4 Standards Considered

9 Costing and Implementation

The intended product price from the Product Design Specification is between £1,700 and £2,200. This price range was selected to be competitive in the e-bike market, by being placed slightly over the average price. Additionally, it is expected that the designed e-bike would not have much competition due to this being an undeveloped market; classic e-bikes as opposed to sport e-bikes.

The calculations are based on an assumption, where a new product is being developed for a large company. Therefore, the overheads will not be considered as the bike will be one of their many products. Furthermore, all the hardware and software have already been purchased.

$$\text{Selling Price} = \text{Profit} + \left(\text{Works Cost Price} + \left(\frac{\text{Cost of Design}}{\text{Quantity}}\right)\right)$$

9.1 Cost of Design

The cost of design describes the price which is invested into each bicycle. This includes the design labour (i.e. the hours spent by engineers directly working on the product), and the cost of the design material. Values for these are provided in the tables below.

Table 5: Specific and total design labour cost

Tasks	Hours (h)	Cost per Hour (£/h)	Total Cost (£)
Developing PDS	3	20.00	60.00
Initial Research	20	20.00	400.00
Market Analysis	6	20.00	120.00
Component Selection	8	20.00	160.00
Material Selection	6	20.00	120.00
Morphological Analysis	3	20.00	60.00
Biomechanical Analysis	5	20.00	100.00
CAD	20	20.00	400.00
Further Development	100	20.00	2000.00
FEA Simulation	20	20.00	400.00
Component Testing	200	20.00	4000.00
Drive Testing	20	10.00	200.00
Total	411		8020.00

Table 6: Specific and total design material costs

Component	Specification	Quantity	Total Cost (£)
Motor	Bosch ActiveLine 250W BLDC	1	250.00
Battery	Bosch Powerpack 300Wh (40 km range)	1	400.94
Charger	Bosch Charger 4A	1	100.00
Front Suspension	SR Suntour XCR-RL Fork Suspension	1	114.95
Back Suspension	M2R Rear Schock Absorber 270mm	1	40.00
Frame	7005-T6 Aluminium (Age Hardening) - 1500g	1	2.93
Wheel	Cast Aluminium - 800g	2	3.12
Tyre	Schwalbe Marathon GreenGuard City (26 in)	2	17.99
Wheel Hub	Cast Aluminium - 300g	2	1.17
Seat	Bioflex Websprung Gents Comfort	1	19.96
Handlebar	Aluminium and Leather Coated	1	25.00
Chain	Shimano HG93 (9 speed) Roller Chain	1	10.99
Headlight	Bobbin Retro Front Light	1	19.99
Brakes	Clarks CMD-11 Mechanical Brake Disc + Rotor	2	11.99
Brake Handles	Shimano BL M425 Acera Brake Lever	2	14.44
Cables	Shimano PTFE Coated Stainless Steel Wire	1	6.99
Pannier Rack	Tortec Velocity Rear Pannier Rack - Silver	1	21.59
Mudguard	SKS Bluemels Mudguard Set	1	25.38
Total			1087.43

Here, retail prices have been taken for components. Therefore, the worst-case scenario is being portrayed. In the case where wholesale prices were to be obtained from the providers, the total cost is expected to drop anywhere from 10% to 20%.

9.2 Works Cost Price

The Works Cost Price includes the price for the salaries of workers which are involved in building the bicycle. Hence, it must include welding costs, casting costs, assembly costs, and testing costs per bike.

Table 7: Specific and total works cost price per bike

Process	Hours (h)	Cost per hour (£/h)	Total Cost (£)
Mechanical Assembly	2	15.00	30.00
Electrical Wiring	1	15.00	15.00
Gas Metal Arc (MIG) Welding	1	30.00	30.00
Low Pressure Die Casting	1	5.00	5.00
Testing	2	20.00	40.00
Total	7		120.00

9.3 Final Cost

Assuming a worst-case scenario where only 100 e-bikes are sold in the first year, the retail price is calculated below assuming a healthy 50% profit margin.

$$\text{Selling Price} = 1.5 \times \left(1087.43 + 120.00 + \frac{8020.00}{100}\right) = £1,931.45$$

This leads to a net profit of £643.82 per bike.

Although this is an elevated price, the following conclusions can be drawn. The cost of producing each bike is £1287.63. This figure has been obtained without considering wholesale prices or economies of scale. Therefore, the total production cost could be expected to decrease by up to 30%. Nonetheless, with the current information, the design fits within the price range specified in the PDS, whilst maintaining a profit margin of 50%. With a maximum profit margin of 80%.

The final selling price can be determined once further market analysis and focus groups are conducted, to understand the current tendencies in the market.

9.4 Break Even Analysis

The following is the break-even analysis conducted for the costs and prices which have been laid out in the above sections. It was also assumed that for the given production capacity, there would be three employees working full time at a standard wage of £23,333 per annum.

Figure 1: Graph displaying the break-even analysis. Break even achieved after 108 units sold.

9.5 Profit and Loss Accounts

The profit and loss accounts have been created for the first three years of the forecasted sales. The expected sales considered as a possibility throughout the first year are 100, 1,000 and 10,000; and a profit and loss account has been calculated for each individually. It was assumed that the number of full time employees required to manufacture 100 bicycles per year were 3, each having a salary of £23,333 per annum (total of £70,000). 30 were required for 1,000 bicycles (total of £700,000), and 300 for 10,000 bicycles (total of £7,000,000). Furthermore, the first year presented two extra costs. This included: design labour costs of £8,200 and tooling costs of £100,000. They are paid off in the first year and from then on, are not considered again.

Taking a conservative approach, a contingency of £10,000 was included for every 100 bicycles produced. Finally, a 20% discount for raw materials was assumed for the 1,000-purchase situation, whilst a 30% discount was assumed for the 10,000 units calculation.

The profit and loss accounts are shown in Table 8 below. Due to the healthy, and comfortable, 50% profit margin imposed on the selling price, only three of the nine considered years would result in a negative profit, with two of them being a minimum loss of £7,743. Therefore, it can be concluded that the product has enough of a profit margin while maintaining a competitive selling price. Additionally, the initial cost projection stated in the PDS has been met in the final design.

Table 8: Expected Profit and Loss accounts for units sold over the first three years

Profit & Loss Account Y1	No.	£	No.	£	No.	£
Units Sold at £1,930.00	100	193,000.00	1,000	1,930,000.00	10,000	19,300,000.00
Costs of Sales at £1,207.43		120,743		965,944		8,452,010
Total Direct Costs		78,020.00		708,020.00		7,008,020.00
Gross Margin		-5,763.00		256,036.00		3,839,970.00
Contingency (with tools)		110,000.00		200,000.00		1,100,000.00
Net Profit/Loss before Tax		-115,763.00		56,036.00		2,739,970.00
Profit & Loss Account Y2	No.	£	No.	£	No.	£
Units Sold at £1,930.00	100	193,000.00	1,000	1,930,000.00	10,000	19,300,000.00
Costs of Sales at £1,207.43		120,743		965,944		8,452,010
Total Direct Costs		70,000.00		700,000.00		7,000,000.00
Gross Margin		2,257.00		264,056.00		3,847,990.00
Contingency		10,000.00		100,000.00		1,000,000.00
Net Profit/Loss before Tax		-7,743.00		164,056.00		2,847,990.00
Profit & Loss Account Y3	No.	£	No.	£	No.	£
Units Sold at £1,930.00	100	193,000.00	1,000	1,930,000.00	10,000	19,300,000.00
Costs of Sales at £1,207.43		120,743		965,944		8,452,010
Total Direct Costs		70,000.00		700,000.00		7,000,000.00
Gross Margin		2,257.00		264,056.00		3,847,990.00
Contingency		10,000.00		100,000.00		1,000,000.00
Net Profit/Loss before Tax		-7,743.00		164,056.00		2,847,990.00

9.6 Return on Investment

The return on investment (ROI) has been calculated for each year of each of the three expected sales scenarios. The results are shown in Table 9 below.

The scenario where 100 bikes are sold never quite becomes profitable. The ROI does improve significantly over the first three years, however, from then on it will tend to a value slightly smaller than one over the years. Therefore, this would require for a slightly higher profit margin. However, the 1,000 bikes sold scenario has a steady increase in ROI, which although not big, still accounts for a 7.11% improvement over the first three years. Therefore, the selling price is well selected for this situation. On the other hand, the 10,000 units sold scenario has a very big initial ROI with a very slight increase over the years. As a result, the profit margin should be decreased to attract more customers and establish the brand better within the market.

Table 9: Cumulative ROI over the first three years of Product launch

Year	100 Units Sold ROI	1,0000 Units sold ROI	10,000 Units sold ROI
1	0.6251	1.0299	1.1655
2	0.7576	1.0605	1.1693
3	0.8152	1.0711	1.1705

10 Project Evaluation

References

Weinert, J. X., Burke, A. F., & Wei, X. (2007). Lead-acid and lithium-ion batteries for the chinese electric bike market and implications on future technology advancement. *Journal of Power Sources*, *172*(2), 938–945.