Final Presentation in ME 4015:
$50 Bicycle for Developing Nations

Sponsor: Dr. Kevin Kochersberger

Darren Barlow
Oliver Donkervoet
Charlotte Ebeling
Veronika Glitz
Wes Kurowski
Jason Luci
Stephen Patterson
Matt Schmidt
Ben Seiden
R.D. Stoepker
Alex Yi

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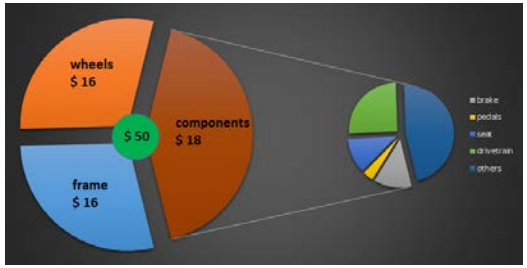
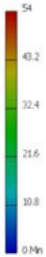
In this presentation, we will explain our concept generation and selection process as well as the consecutive analysis

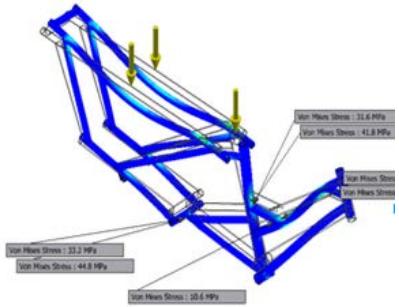
Customer needs



CAD model of cargo bike



FEA analysis



Wheel and Component designs

Outlook

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Our goal is to produce a bicycle for $50 that is simple in design and eases the strain of transporting goods and services

www.bbc.com

Promote eco-friendly transportation

Increase mobility of population in developing nations

Improves quality of life of target user group

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Based on research about the situation in the developing nations and the client's expectation we set up the customer needs

Importance

Affordability	**$ 50**
Durability	**on unpaved roads** **puncture resistant tires**
Repairability	**easy maintenance**
Cultural adaptability	**women with long dresses**
Comfort	**long difficult rides**

horizonsunlimeted.com

Developmentalidealism.com

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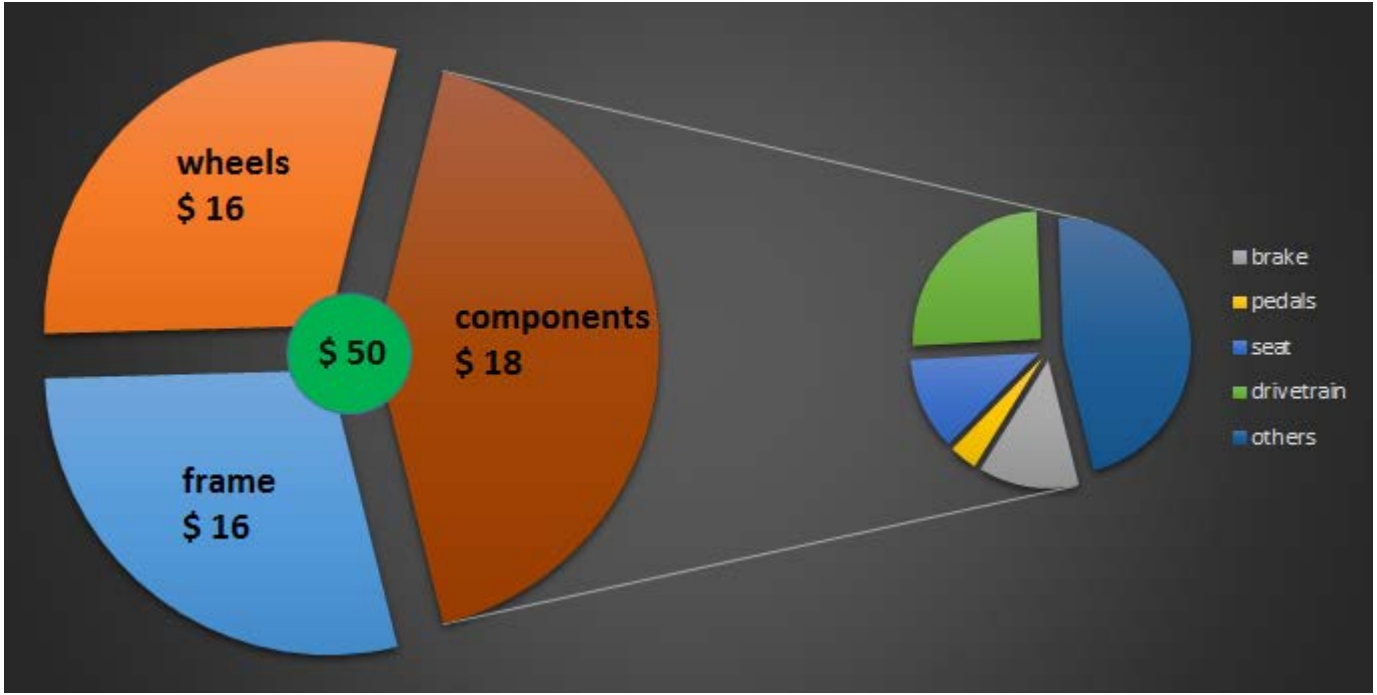
Based on research about the situation in the developing nations and the client's expectation we set up the customer needs



Within the design process we want to meet the engineering requirements of a cheap, durable, and sustainable bike

Engineering Requirement	Category	Specification	Threshold	Target
Resistant to Environmental Influences	Wheels	Tire Temperature	-10°C to 50°C	-20°C to 60°C
	Tires	Average Miles Travelled Before Puncture	2000 km	5500 km
Rolling Resistance	Wheels	Required Power at 20 kph and 85 kg Bike & Rider	250 W	205 W
Shall be Capable of Sustaining Forces	Wheels	Vertical Forces	2.5 kN	5.0 kN
	Wheels	Rolling Resistance @ Max Loading Capacity	50 N	30 N
	Wheels	Torque	80 Nm	100 Nm
Bike Should be as Cheap as Possible	Overall	Cost	$85	$50
Environmentally Sustainable	Overall	Recyclabe Material	60%	90%
	Overall	Production Waste	40%	10%

Engineering Requirement	Category	Specification	Threshold	Target
Carrying Capacity	Back rack	Carrying Capacity	100 kg	150 kg
	Saddle	Carrying Capacity	80 kg	100 kg
Functional Geometry	Frame	Persons of Height	150 cm - 170 cm	120 cm - 190 cm
Durability	Frame	Lifetime	7 Years	15 Years
	Component	Lifetime	3 Years	6 Years
	Wheels	Lifetime	2 Years	3 Years
Reparabilty	Frame	Number of Tools Required	5	2
	Wheel	Number of Tools Required	3	1
	Components	Number of Tools Required	3	1
Cultural Awareness	Frame	Type of Frame	Standard	Step Through
	Components	Pedals	Standard	Barefoot Compatible
Security	Components	Locking Mechanism	None	Included
Handling	Overall	Weight	40kg	15kg

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We chose to explore a multitude of solutions for the functional aspects of our bicycle

Feature	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5
Material	Aluminum	Bamboo	Carbon Fiber	Steel	Wood
Frame type	Step Through	Long Frame	Recumbent	BMX Style	Tricycle
Wheel Size	20"	24"	26"	29"	26” X 4”
Wheel Type	Tweel	Conventional Spokes	Solid Wheel	Sprung Metal	Welded Spokes
Brake type	Fixed Gear	V-Brakes	Disc	Coaster	Drag Feet
Drivetrain	Direct Drive	Belt	Chain	Feet	Driveshaft

Long Bike Concept	

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A CAD model of our cargo bike design was created using the Autodesk Inventor

adjustable seat with a capacity of 100 kg

long backrack with loading capacity of 140 kg

simple, commonly available steel tubes

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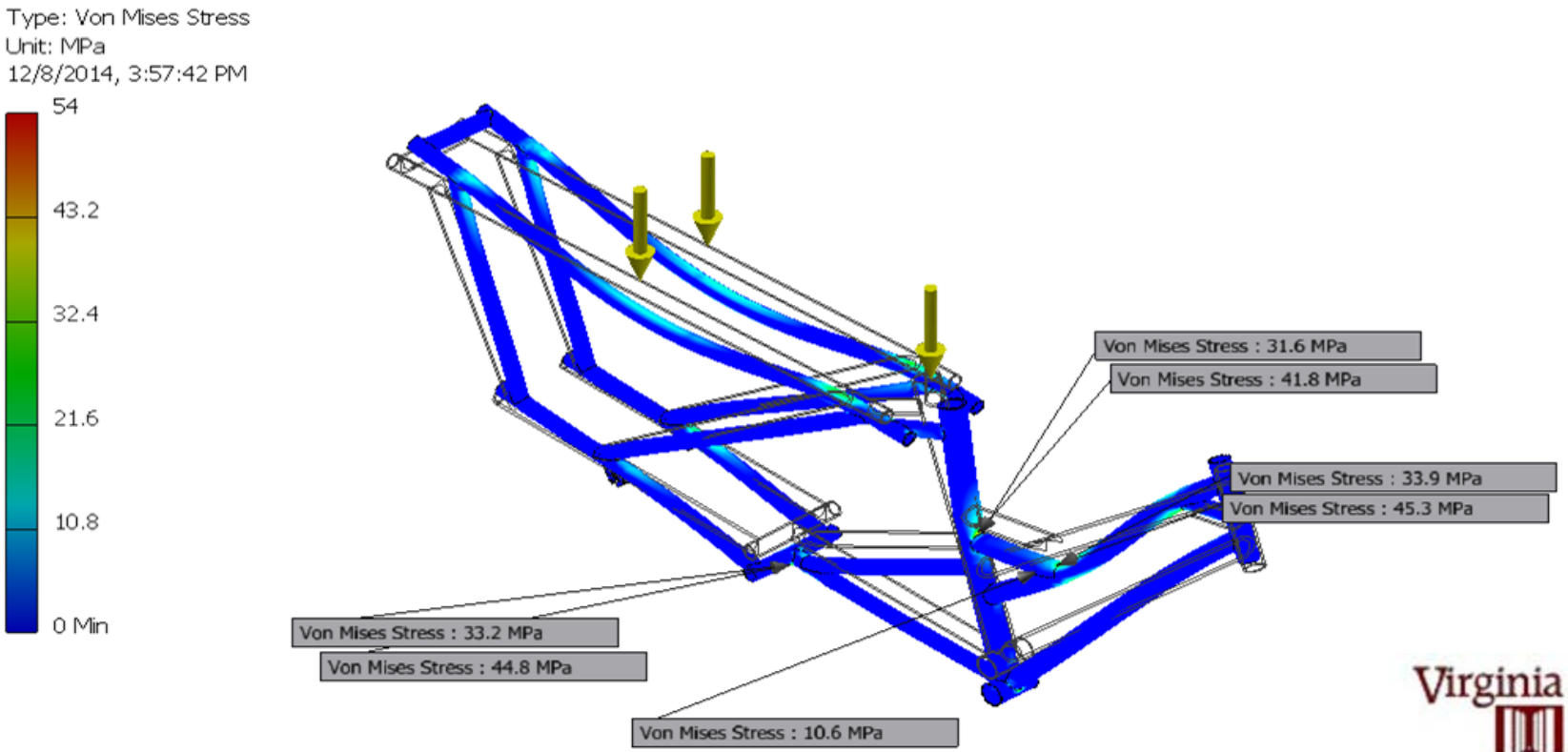
Considering Design for Manufacturing and Assembly, we guarantee low cost and repairability

Streamlined bearing designs across the bike

easy welds according to welding guidelines

Stress analysis on the frame showed that the frame of the cargo bike can carry 240 kg



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Estimating material and manufacturing costs for Developing Nations is linked to a high uncertainty

	Price per frame ($)
Welding and assembling cost from labor	1
Filler material cost	1.48
Shielding gas cost	1.59
Cost of power consumption	0.06
Material cost (8m steel tube)	11.32
Total frame set	15.45

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Five components of the bicycle were considered for production

Drivetrain		Saddle	Pedals	Brakes
				
Characteristics				
30T chainring 16T cog	73x110 Bottom Bracket	Selle Master Saddle	2x1in steel tubes with bushing/bolt attachment	rear coaster brake front v-brake

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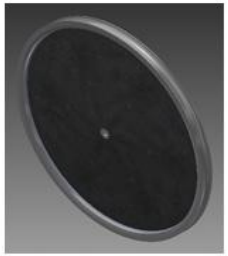
Several wheel designs have been generated and compared

The three different designs for a 26'' wheel		
Conventional Wheel	Disc Wheel	6-spoked Wheel
		
Spoke characteristics		
36 spokes 3 cross spoke pattern Spoke cross section: circular Spoke diameter: 1mm	No spokes, instead: 2 conical steel plates	6 spokes 0 cross spoke pattern Spoke cross section: rectangular Spokes: 5mm x 30mm
Rim characteristics		
		
Tube characteristics		
Conventional air filled tube 	"Milele" tube made out of full rubber material 	
General		
Weight: 1.8 kg Materials: Alloy, steel spokes Cost wheel set: $23.28	Weight: 20kg Material: commercial quality mild steel (S235) Cost: $47.60	Weight: 2.569 kg Material: commercial quality mild steel (S235) Cost wheel set: $32.75

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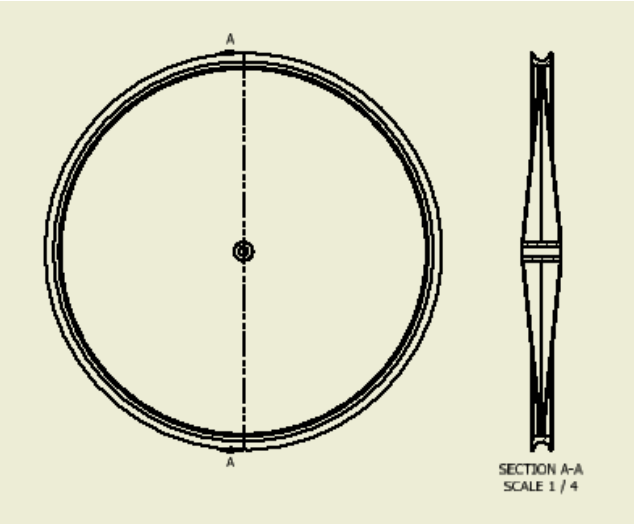
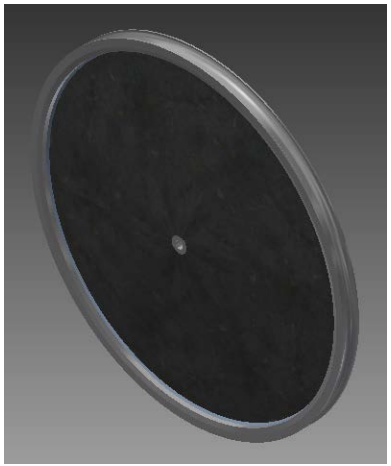
The first self manufactured wheel design is composed of two conical steel plates



Front view of wheel and cross section

2mm thickness



Two conical steel plates are welded contrarily at the hub and rim

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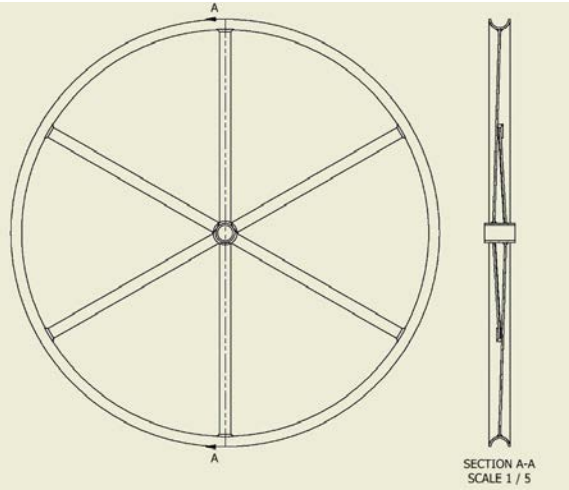
The second wheel design is characterized by a 6 spoke pattern made out of steel flats



Front view of wheel and cross section

30mm x
5mm

Steel flats are welded at hub and rim having different angles to increase bending stiffness

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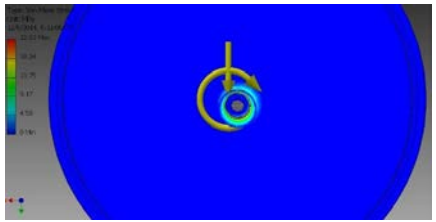
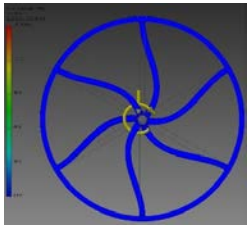
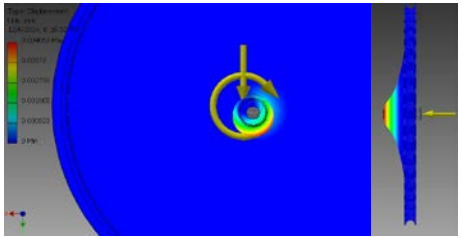
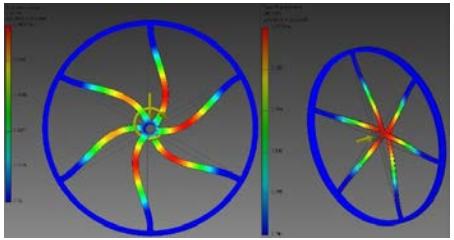
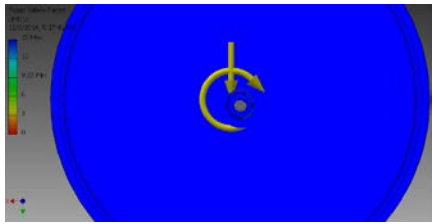
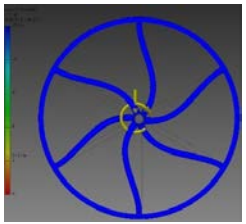
Finite Element Analysis was conducted to examine feasibility of each wheel design

Disc wheel design	6 spoke wheel design
 Von Mises stress	 Von Mises stress
Displacement 	Displacement 
 Safety factor	 Safety factor

The results of the Finite Element Analysis show that both designs are durable

Table of results for Von Mises stress, displacement and safety factor

	Disc Wheel	6-spoked Wheel
FEA based on a vertical force of 1134 N and a torque of 118 Nm at the hub during the braking process		
Von Mises stress [MPa]	23	75
Displacement [mm]	0.0047	0.06
Safety factor	9	3.41
FEA based on a bending force of 500N at the hub		
Von Mises stress [MPa]	9.86	72
Displacement [mm]	0.025	1.27
Safety factor	15	5.67

Modification of plate design

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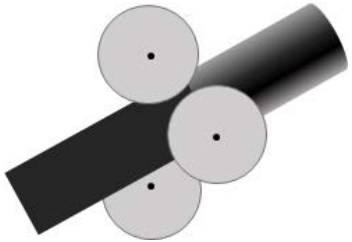
Local manufacturing requires easy processing and use of common tools and materials

Spoke wheel

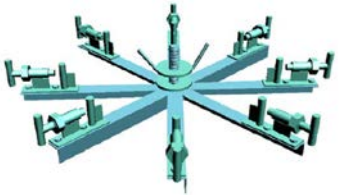
1. Rim bending
2. Spoke cutting
3. Gas welding



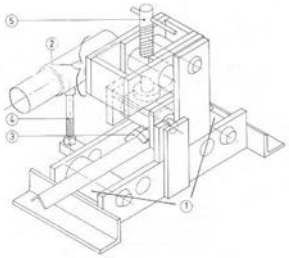
rim bending device

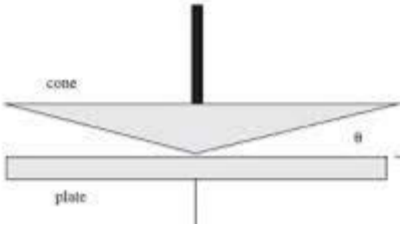
Disc wheel

1. Rim bending
2. Plate cutting
3. Plate stamping
4. Spot welding



manufacturing jig for welding





conical stamp

The results of the proposed wheel testing plans will finally decide on the wheel design

Testing plan for the different wheel components and specifications

	Design Specification	Target Value	Threshold value	Test
Whole Wheel	Total Weight support	125 kg	90Kg	Static loading test, frontal stiffness
	Deformation (125 kg)	0 cm	2 cm	Static loading test, frontal stiffness
	Deformation (5 m)	0 cm	4 cm	Drop Test
	Lifespan (50 mile)	0 cm	2 cm	Trueing test after 50 mi, lateral stiffness
	Ease of Repair	0	4	# of tools
	Ease of Repair	15min	2 hours	amount of time
Tire	Puncture resistance	500 N	250 N	Increasing puncture force (screw driver)
	Lifespan	<10g lost	25 g lost	Weight difference after 50 mi
	Rolling Resistance	0.0022	0.005	Coefficient of rolling resistance (45psi, 15km/h)
	Erosion resistance	10g	25g	Acid/salt test (2 hrs, gasoline) Weight difference of tire
Rim	Compression (static)	1000N	500N	pressure test
	Tension (static)	1000N	500N	pull test
	Bending	50N	25N	Force needed until deformation of 1cm
	Compression/Tension (dynamic)	500N	250N	10000 cycles
Spokes	Compression (static)	50N	20N	pressure test
	Tension (static, dynamic)	50N	20N	pull test
	Bending	20N	10N	Force needed until deformation of 1cm
	compression/tension dynamic	25N	10N	10000 cycles
Tube	Puncture resistance	200N	100N	Increasing puncture force
	Maintaining pressure	0 psi lost	1 psi lost	(45 psi, measure again after 5 days)

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The cost analysis is based on local manufacturing of the designed wheels

Composition of wheel manufacturing and material cost

	Two plates Wheel	6-spoked Wheel
welding and assembling cost from labor	$0.25	$0.25
Rim, hub, spokes parts manufacturing cost from labor (bending, cutting and rolling)	$0.15	$0.05
Filler material cost	$0.37	$0.37
Gas cost	$0.40	$0.40
Cost of power consumption	$0.05	$0.05
Milele tube and tire	$4.5	$4.5
Material cost	$18.08	$11.77
Total wheel	$23.80	$17.39
Total wheel set	$47.60	$34.78

Retail price of a cheap conventional wheel set: 29.1% of total cost

$23.28

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50% of the deliverables for the project have been completed

Complete ~ 50%	Pending ~ 50%
● Frame CAD Model ● Three Wheel CAD Models ● Wheel FEA ● Frame FEA ● Components ● Establish design specs and testing standards	● Testing/Fabricating wheels ● Fabricate frames for testing/shipping ● Order components

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We are planning to have a first prototype bike ready by February to do field testing in Senegal

Date	Milestones/Deliverables
Jan 20, 2015	Begin testing of specific parts of the bike
Feb, 2015	Fabricate bike
End of Feb, 2015	Goal is to have our first prototype bike ready to be shipped to Senegal for field testing
March, 2015	Optimize our design
March 23, 2015	Product launch
May 4, 2015	Final design

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In conclusion, we are in the process of designing an affordable bicycle for manufacture and use in developing countries

Focus of design: Affordability and ease of manufacturing

Frame team: CAD analysis and prototype

Component team: saddle, brakes,pedals, drivetrain

Wheel team: wheel testing for final selection

Goal: Prototype by mid February

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