

Development of a Permanent Bicycle Chain Maintenance and Cleaning Device

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This article aims to develop an innovative solution for the dirt accumulation challenges faced by long-distance cyclists in maintaining their bicycle chains clean and functional for longer periods. The methodology employed involved a detailed analysis of existing products on the market, identifying their strengths and weaknesses. This comparative analysis served as the basis for the development of an optimized product capable of withstanding adverse weather conditions, ensuring continuous lubrication, and preventing the accumulation of dirt. The results achieved demonstrate the feasibility of a solution that extends the lifespan of the chain, reduces the need for maintenance, and significantly improves the performance and safety of cyclists, allowing them to focus exclusively on their cycling experience.

Keywords: Lubrification. Transmission. Bicycle. Chain. Performance. Maintenance.

The bicycle chain is a critical power transmission component whose performance is compromised by particulate accumulation and insufficient lubrication, leading to accelerated wear, reduced efficiency, and even safety risks as pointed by REI [1]. This issue is particularly acute for Mountain Bikes, which are not only the market's most popular category, sold by over 90% of stores in Brazil, according to Aliança Bike, 2024 [2], but are also the most affected by contamination in off-road environments (e.g., Figure 1), where indispensable maintenance procedures are laborious and impractical.

The sector's financial health, with an average 2023 gross revenue of R\$500,000 per shop in Brazil [2], underscores the commercial opportunity for innovation. While various solutions exist, a permanent, integrated device providing efficient, autonomous maintenance has not been effectively realized. The primary objective of this project is to address this challenge by developing a product that ensures sustained chain function, thereby enhancing reliability and allowing cyclists to focus entirely on performance. The realization of this concept follows a

structured product development methodology, which this article document from the initial informational design through to the final project specifications.

Materials and Methods

This methodology applied to this project was the Product Development Process (PDP) which is based on the issue observation, going through 17 steps of investigation, raising customer needs, identifying product requirements up to concept development and final product definition.

Throughout the development process, various strategic tool and concepts were employed. This project started by identifying an issue, which was the short durability of bicycle chains that are recurrently submitted to off-road trails (Figure 1). This issue was raised during a brainstorm session from the team members based on personal knowledge and experience, as some of the members have track riding experience.

The next step was an extensive bibliographic review through e-commerce pages to identify the currently available solutions, how they function and identifying improvement opportunities.

Once the opportunity was identified and the competitors were mapped, the team came up with a questionnaire "Problemas de sujidade no sistema de transmissão de bicicletas em trilha"

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Figure 1. Dirty bicycle after an off-road ride.



Source: Transbike [3].

[4] on Microsoft Forms to deepen the knowledge of the real customer needs and pain points. The questionnaire was shared to cycling groups and received a 32 responses, that greatly contributed to the development.

The questionnaire was used to map the client's needs, by applying Global Functions and Functional Synthesis tools, which has helped in translating the responses into functional requirements which were applied on the next phases.

The functional requirements were input onto the QFD, TRIZ and Morphological Matrix, which resulted of robustness of 5 concepts, leading to the final Solution selection.

The PDP methodology used on this process has been developed and described by authors Back and colleagues (2008) [5], Baxter (1998) [6] and Rozenfeld (2006) [7].

Results and Discussion

Interfaces

The intricate interplay between the cyclist, the bicycle, the external environment (trails, forest, mud, etc.), creates a complex web of factors that directly influence the performance and durability of the drivetrain; accumulated dirt can compromise pedaling efficiency, increase wear on parts, generate annoying noises, and, in extreme cases, lead to mechanical failures that interrupt the

cyclist's experience. In this context, understanding the nuances of this relationship (how trail type, weather conditions, cyclist maintenance habits, and component quality combine to determine drivetrain dirtiness) is crucial for mitigating negative effects and ensuring a smoother, more efficient, and long-lasting ride, this scenario is addressed by a system-problem diagram (Figure 2).

Benchmark

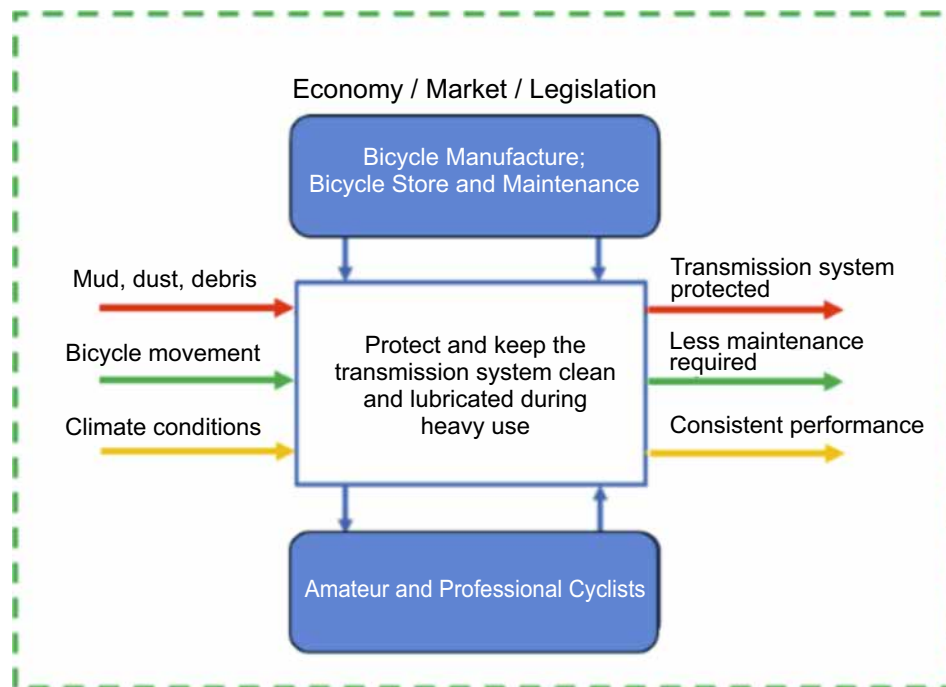
Prior to conceptualizing our product, a comprehensive benchmark study was undertaken. This systematic comparison of existing market solutions aimed to identify their operational mechanisms, pinpoint their strengths and weaknesses, and ultimately uncover opportunities for competitive differentiation. The research revealed that while current offerings span categories such as chain cleaners (special soaps and degreasers), active cleaning equipment (brushes and microfiber yarn), semi-automatic cleaners (attachable devices with rotational mechanisms), and chain covers, none adequately address the comprehensive needs outlined for our proposed solution, thereby highlighting a clear market gap (Figure 3).

Besides different products aimed to be used on the traditional bicycle transmission system made of a chain and sprockets, the study uncovered other unconventional transmission systems like a belt driven drivetrain and driveshaft connected system that promise to deliver a more robust system that don't require active cleaning and lubrication of the system.

Customer Needs

Data from the questionnaire [4], combined with market research on similar products allowed for the identification of key customer needs and a comprehensive understanding of consumer expectations. These needs were subsequently translated into a concrete set of design requirements.

The requirements serve the critical function of converting abstract customer needs into a precise,

Figure 2. System-problem interface diagram.**Figure 3.** Identified competitors.

1. Chain cleaner [8] 2. Attachable device [9]. 3.Brushes [10]
4. Cover [11].

technical language with measurable characteristics. This conversion establishes an objective framework to guide and validate all subsequent design efforts. These are subsequently used as the starting point of the QFD (Quality Function Deployment) process.

QFD

The result of applying the QFD method resulted in 10 needs identified for 3 specific types of customers, in which each one received a different weight. To the manufacturer it was given 10% weight, to the sales rep. 30% and to the end user 60%. Based on the results obtained from the questionnaire [3], a grade was attributed to each of the identified needs. That information collected resulted in a total of 13 requirements being translated. The end results of the methodology we observed in Table 1 and Table 2, which brings the product's lifespan increase as the highest scoring requirement.

TRIZ

Once the customer needs were identified, translated to requirements and systematically analyzed and scored through the use of QFD. Translated as "Theory of Inventive Problem Solving" it is a strong methodology that helps foster innovation and solve complex technical

Table 1. Correlation between needs and project requirements.

#	Client	Need	Client's Weights	Client's Grades	Production Cost	Number of Components	Standardized Components	Product's Volume	Efficiency Loss	Selling Price	Installation time	Installation Special Tools	Weight	Time between maintenances	Maintenance time	Cleaning time	Lifespan
					#	#	#	mm ³	%	R\$	min	#	g	weeks	min	min	km
					↓	↓	↑	↓	↓	↓	↓	↓	↓	↑	↓	↓	↑
A	Manufacturer	Low cost of production	10%	9	8	4	4	2	0	8	0	0	2	0	0	0	4
B	Seller / Market Place	Install needs to be done without user special expertise	30%	9	0	2	2	0	0	4	8	8	0	0	2	2	0
C	Consumer / User	Product will be used with low need of special tool	60%	3	0	0	0	0	0	4	4	8	0	0	4	0	0
D		Product needs to be small	60%	1	2	0	0	8	0	2	0	0	4	0	0	2	0
E		Product is light so it doesn't bother the cyclist on a ride	60%	1	2	0	0	4	0	2	0	0	8	0	0	0	2
F		Resistant to continuous use with low maintenance	60%	9	8	2	0	0	4	4	0	0	2	8	0	0	8
G		Low purchase price	60%	6	8	4	4	2	0	8	0	0	2	0	0	0	4
H		Low to no maintenance	60%	6	0	4	0	0	4	4	0	0	0	8	8	4	8
I		Product needs to maintain itself clean	60%	9	0	0	0	0	8	0	0	0	0	4	2	8	8
J		Product will maintain cyclist's performance	60%	1	0	0	0	0	8	0	0	0	2	8	2	0	8

Requirements' Priority Ranking

82	82	49	23	16	84	92	29	36	28	98	53	64	139
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Table 2. Roof of the house of quality matrix.

Legend:	2	Very Positive Relation																							
	1	Positive Relation																							
	0	Neutral																							
	-1	Negative Relation																							
	-2	Very Negative Relation																							
												Lifespan													
												Cleaning time		0											
												Maintenance time		2	0										
												Time between maintenance		0	0	2									
												Weight		0	0	0	0								
												Installation Special Tools		0	0	1	0	0							
												Installation time		2	0	0	1	0	0						
												Selling Price		1	1	-1	-2	0	0	-2					
												Efficiency Loss		-1	0	0	0	2	0	0	1				
												Product's Volume		0	-1	0	0	1	0	0	0				
												Standardized Components		-1	0	2	0	2	-1	0	0	0			
												Qty of Components		0	1	0	1	2	1	1	0	1	1	0	
												Production Cost		0	0	1	0	-2	0	0	2	1	0	0	1

problems by using universal patterns of innovation to identify and resolve contradiction inherent in design requirements. The four inventive principles resulted from the methodology (Table 3) helped in drafting what would be the first concepts of the proposed solution and would be the base of the Morphological Matrix.

Morphological Matrix

With the previous steps completed and rough drafts generated a morphological matrix was started to assist in defining the functions that each concept would address in order to meet the solution proposed by the initial problem.

During this phase, five alternative solutions emerged (Table 4) that cross-combined eight elemental functions to address the bike drivetrain's three core functions: protection, lubrication, and cleaning.

Concept Selection

The concepts were evaluated with the Pugh Matrix, in which customer needs and their respective weights (derived from the QFD) served as the decision criteria. "0" indicated parity with the datum, "+1" superior fulfilment and "−1" inferior fulfilment.

The concepts idealized were: C1: PTFE-coated chain plus curved-tooth scraper; C2: PTFE-coated chain plus super-hydrophobic spray; C3: Full protective sleeve with passive wax dripper; C4: Handle-bar-actuated dripper with twin brushes; C5: Rear-derailleur housing filled with bees-/carnauba-wax.

Two progressive screening rounds comparing the concept with other market products and were made. First against the cover (Table 5), and finally head-to-head (Table 6), ranked the candidates and revealed the most promising ideas according to the attendance of customer needs.

Tables 5 show that Concept 2 consistently outperformed the datum and its peers, obtaining net scores of +16.2.

Table 6 reveals that, when the concepts are compared exclusively among themselves, Concept 5 achieves the highest overall score, closely followed by Concept 2. In contrast, Concepts 1, 3 and 4 deliver only marginal or even negative benefits: they add excessive mass, demand specialized installation tools, or drive the product cost beyond an acceptable level.

A hybrid solution, hereafter Concept 6 (e.g., Figure 4) was therefore synthesized by merging the two front-runners: the low-friction, factory-impregnated PTFE chain from Concept 2 and the compact wax-reservoir envelope from Concept 5. This combination retains the self-cleaning advantage of the hydrophobic coating while adding a continuous, solid-phase lubricant that re-coats the rollers as they pass through the felt applicator. So the Concept 6 fulfils all three key functions identified as essential to the product.

Conclusion

This work introduces a compact module that simultaneously protects, lubricates, and cleans bicycle drivetrains by pairing a low-friction, PTFE-treated chain with a solid-wax reservoir and felt applicator. The concept emerged from a structured design route that blended QFD priorities, TRIZ contradiction mapping, morphological recombination, and multi-stage Pugh screening, ensuring that customer value, technical feasibility, and cost discipline were addressed in parallel.

In summary, the proposed drivetrain module advances bicycle reliability and sustainability while remaining sensitive to cost and ease-of-use. Widespread adoption could lower maintenance burdens for riders, minimize lubricant waste and set a new benchmark for eco-efficient cycling components. Achieving full market readiness will require extended field testing, fine-tuning of material formulations, and collaboration with supply-chain partners to establish circular end-of-life pathways. Nevertheless, the proposed module stands poised to raise performance standards across the cycling sector.

Table 3. Inventive principles indicated by the TRIZ method.

Contradiction	Improving Parameter	Worsening Parameter	Inventive Principle
Lifespan vs Selling Price	16. Durability of nonmoving object	32. Ease of manufacture	10. Preliminary action 35. Parameter changes
Lifespan vs Selling Price	15. Durability of moving object	32. Ease of manufacture	27. Cheap short-living objects 1. Segmentation 4. Asymmetry
Standardized Components vs Weight	36. Device complexity	1. Weight of moving object	26. Copying 30. Flexible shells and thin films 34. Discarding and recovering 36. Phase transitions
Selling Price vs Efficiency Loss	21. Power	32. Ease of manufacture	10. Preliminary action 26. Copying 34. Discarding and recovering

Table 4. Morphological matrix.

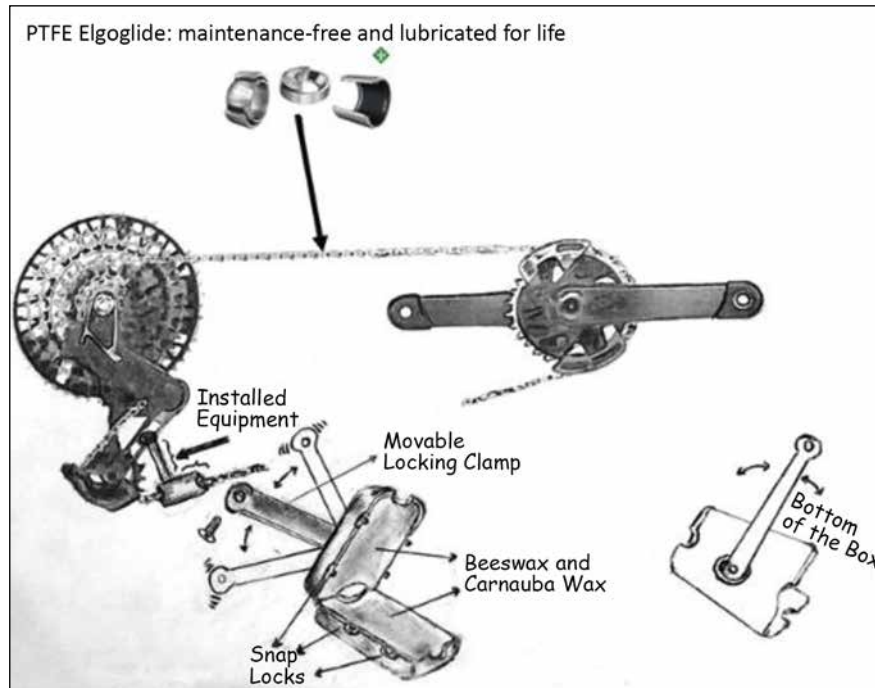
Function N1		Function N2	S1	S2	S3	S4	S5	S6
F1	Install Product to bicycle	Clean Transmission	 Brush	 Nylon "Floss"	 Water Jet	 Cloth	 Compressed air	 Grease remover
F2		Fix product to system	 Screws	 Nylon Clamps / Hellermann tie	 Snap Fit	 Adhesive	 Metallic Clamp	 Weld
F3		Regulate / Adjust product	 Manual	 With tools				
F4	Check functionality	Ensure functionality	 Visual	 Level	 Engagement	 Moving the system	 Luminous	 Audible
F5	Protect the transmission system	Ensure system protection	 Cover	 Chemical (hydrophobic)				
F6		Ensure lubrication	 PTFE	 Manual application of liquid lube	 Semi-automatized	 Automatized liquid lubrication	 Passive liquid lubrication (immersion)	 Solid Lubrication (grease / wax)
F7		Ensure system cleanliness	 Cover	 Scraper	 Brush	 Centrifugal Force		
F8	Verify system integrity	Ensure system integrity	 Visual	 Level	 Engagement	 Moving the system	 Luminous	 Audible

Table 5. Generated concepts vs protective cover.

#	Client	Need	Grades	Weights	I	II	III	IV	V
A	Manufacturer	Low cost of production	9	10%	-1	-1	-1	-1	-1
B	Seller / Market Place	Install needs to be done without user special expertise	9	30%	0	1	0	0	0
C	Consumer / User	Product will be used with low to no need of special tool	3	60%	0	1	0	1	0
D		Product needs to be small	1	60%	1	1	0	1	0
E		Product is light so it doesn't bother the cyclist on a track ride	1	60%	1	1	0	1	0
F		Resistant to continuous use with low maintenance needs	9	60%	1	1	1	1	1
G		Low purchase price	6	60%	-1	-1	-1	-1	-1
H		Low to no maintenance	6	60%	1	1	1	1	1
I		Product needs to maintain itself clean	9	60%	1	1	1	1	1
J		Product will maintain cyclist's performance	1	60%	1	1	1	1	1
				Total	11.7	16.2	10.5	13.5	10.5

Table 6. Generated concepts vs concept 2.

#	Client	Need	Grades	Weights	I	II	III	IV	V
A	Manufacturer	Low cost of production	9	10%	-1		1	1	1
B	Seller / Market Place	Install needs to be done without user special expertise	9	30%	-1		-1	-1	-1
C	Consumer / User	Product will be used with low to no need of special tool	3	60%	-1		-1	-1	0
D		Product needs to be small	1	60%	-1		-1	-1	-1
E		Product is light so it doesn't bother the cyclist on a track ride	1	60%	-1		-1	-1	-1
F		Resistant to continuous use with low maintenance needs	9	60%	0		-1	-1	-1
G		Low purchase price	6	60%	-1		1	1	1
H		Low to no maintenance	6	60%	0		0	0	0
I		Product needs to maintain itself clean	9	60%	1		0	0	1
J		Product will maintain cyclist's performance	1	60%	0		0	0	0
				Total	-4.8	0	-6.6	-6.6	0.6

Figure 4. Concept 6.

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