Dat Bike

Electric Motorcycle - Made in Vietnam

DATBIKE

A short documentation of the history of this company,
the current situation and possible future developments.

v0.8

2021/12/16

Table of contents

1 The company

One important detail about any startup aside from their business idea is the people behind this idea. The team. Who are they, where do they come from, what is their background and expertise?

1.1 Management, CEO and R&D

Nguyễn Bá Cảnh Sơn, founder of the company. Born in 1990 and with a master degree in computer science from the University of Illinois [saostar2019]. Developed the idea in February 2018 in California over the period of 6 months [khpt2019] and brought the idea to his hometown, Da Nang [dautu2019] in November 2018. Later moved operations to Bing Duong and Ho Chi Minh City.

Gong, best friend of Son. A software engineer too? Or the mechanical designer of the frame and swingarm? Second partner of this company?

There is Thinh (BLDC driver software and PCB design).

Trang (battery controller, configuration)

And Dat Vo helped optimize the production in Binh Duong up from 1 bike/day.

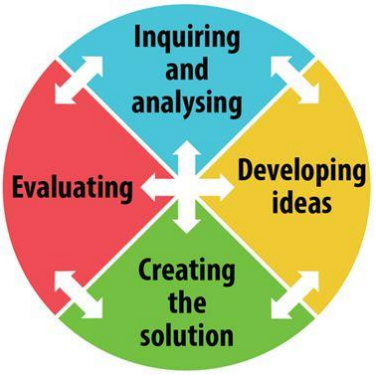
One student from FabLab created a biometric fingerprint sensor and analyzed electric specifications of BLDCs in real world situations.

1.2 Procurement, Humans resources, Assembly and Marketing

The interview from November 28th, 2019 [dautu2019] states that the company has around 50 people in production and development and can produce 1000 bikes/month in Binh Duong.

As of December 2020 there is an open job position in marketing, posted on the website since November 11th - in english?

Another online update surfaced on April 13, 2021. With a pre-Series A funding of $2.6 million from Jungle Ventures there was an extensive article on techcrunch, techinasia, vnexplorer, vir, and in Vietnamese by cafeland, ndh, nhipcaudautu,



1.3 Product

In December 2020 the company offered only **one** bike with only **one** color option, the **Weaver**. The registration values [vr2020] at vr.org.vn state some of the following technical data of this bike.

- Motor 3000 Watt sustained, peak 4500 W [dautu2019] or 5000 W (website, registration)
- Weight 85kg (35/50), max weight 215kg (max load 130kg? Two 65kg persons?)
- 1840 x 730 x 1000 mm, wheelbase 1270 mm
- Wheels 70/90-17 and 80/90-17
- Disk brake front and rear
- Battery 72V, 29Ah (2088 Wh)
- Price: 39,000,000 VND (ca. 1720 USD)
- Sold: 60 in September 2019 [cafeland2019], 200 in January 2020 [dauto2019]
- Production price 25M, selling point 40M, gross sales 8ty, gross profit 3ty - 130,000 USD

Update 27.11.2021 - Weaver 200

On November 27th dat.bike announced an updated weaver as second model, the Weaver 200:

- Motor peak 6000 Watt (website, registration at vr.org.vn) on the official registration site only the QSMOTOR 72V3000W but now with 5.6 kW which is not 6 kW
- Weight 120kg, max load 165kg - registered with 105kg and max130kg like before)
- 1900 x 750 x 1100 mm, wheelbase 1290 mm
- Wheels 70/90-17 and 80/90-17
- Disk brake front and rear, generative rear brake
- Battery 72V, 68Ah (4896 Wh)
- Price: not yet found

The dat bike app in the Apple Appstore was published as 1.0. Not on Google Play, though.

1.4 Offices, Shops, Manufacturing and R&D

In the beginning of 2019 Dat Bike opened an electric bike **rental service** in Da Nang, located at 23 Nguyễn Thái Hoc. It was closed in 2020 and the 10 bikes were transported to the new assembly and testing area at the Eastern International University.

The main office is now located at Block B11, Trường ĐH Quốc Tế Miền Đông, Khu vực thành phố mới, Thủ Dầu Một, Bình Dương at the Eastern International University. **R&D** and **assembly** is done there. Opened in September 2019.

A second production facility assembles the bike's **batteries**. It is located at - khong biet. Update December 2020: It is relocated in-house to ensure high quality.

On November 21st, 2020 the **store** 49b Tú Xương, Phường 7, Quận 3, Thành phố Hồ Chí Minh opens.

The official website now is https://dat.bike/ . Historically it looked like this in February 2019.

Update 16.12.2021

With the funding the team is about to expand. Open positions include:

- Back office: Talent Acquisition, HR Manager, HR Intern, IT Administrator

- Marketing: Graphic Designer, Product Marketing, Performance Marketing, Content and Community, Senior Brand Marketing Manager
- Production: Quality Engineer, Process Engineer, Logistics Coordinator, Purchasing Associate, Procurement Associate
- R&D: Software Engineer, Industrial Designer, R&D Prototyping Engineer, Lead/Senior Software Engineer
- Sales: Customer Service, Sales Executive, Sales Trainee, Sales Operations, Operations Manager, Service Technician

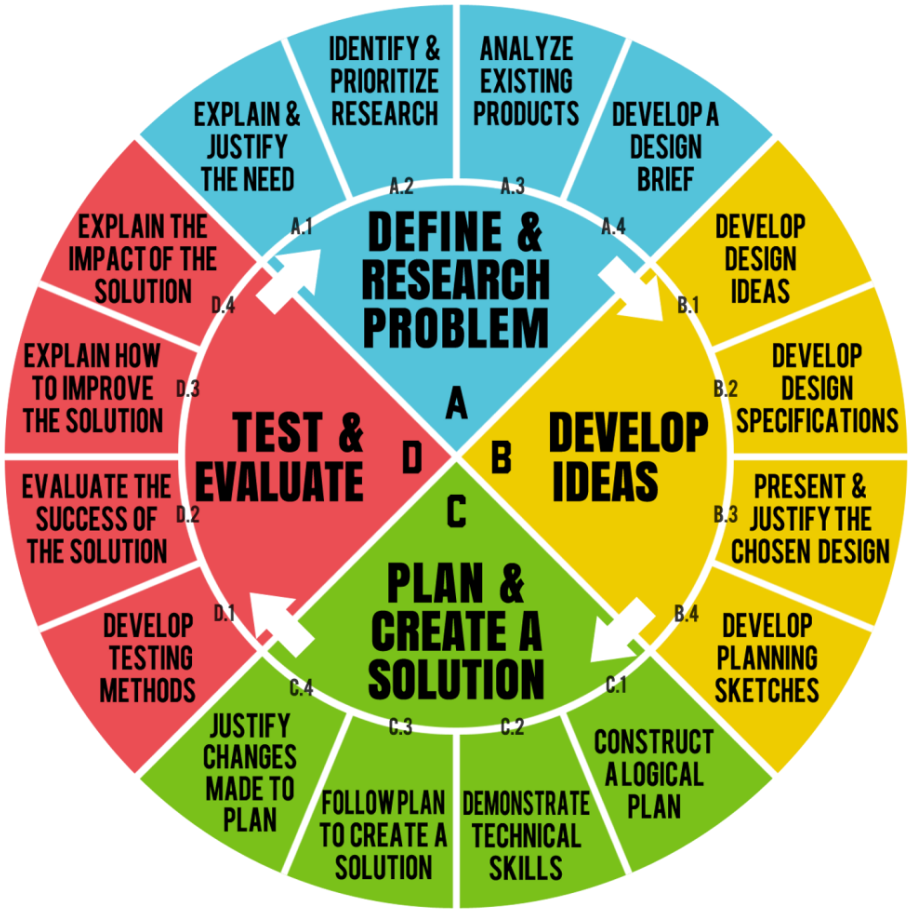
1.5 Market value

The value of the company was estimated at 3,000,000 USD (2% equals 60,000 USD investment from Shark Nguyen Thanh Hung, Vice President of CenGroup [dauto2019]) to 6,000,000 USD [saostar2019].

In April 2021 the company received a pre-Series A funding led by Jungle Ventures of $2.6 million.

2 Design History

Initially I simply wanted to document the history of the company. But each historic step involved a challenge, change and adjustment to the current situation. In most cases it reflected a step in the design cycle. And since I'm a certified design teacher (see here) I included the certain stage of a cycle into the documentation to highlight improvements and areas of growth.



For reference I included a more refined cycle from the MYP program. Of course the general design process can be broken down differently, but for later consistency I would like to refer to the 4 main steps and smaller 16 steps.

2.1 First prototyping - v0.1 in California April 2018

In February 2018 Son quit his job and started to learn about electric bikes for 6 month. Not just watching youtube videos for 10 hours [khpt2019] but building first prototypes in April 2018. This development phase is partly documented in this video from April 2019.

This matches pretty much the (A) Inquiry and Analyze part (lacking A.3) and (B) Developing ideas part of the design. The prototypes C.2 Demonstrate the technical skills.

The flat seat, rather boxy battery, two-tubes frame design and high center of mass for high clearance or space to mount the engine originates from these initial designs. The early name was Gausscycle.

The search for angel investors in silicon valley was not successful [khpt2019], but his hometown Da Nang has an incubation center (video) to support his idea.

2.2 Updated design samples - v0.2 in Vietnam November 2018

No visible design adjustments to the design, developed in California. Details are adjusted to the local production capabilities. While 3 hour charging time sounds great, not everybody has a power outlet next to the parking space. Usually electric bikes can remove the battery therefore. This was also tried to implement in the design of dat bike:

You see on the right that it was intended to hang the battery to the frame and remove it for charging. The aluminum battery case has two more planned connection points, one on the bottom and a small one in front. In the end the battery was fixed to the frame and is no longer removable. It looks like *D.2 Evaluate the success of the solution* and that the tradeoff for the removable battery with this design (no second enclosure for the battery pack) with increased instability justified the design change to a fixed mounted battery.

Another design flaw in the location of the foot rest for rider and socius can be traced back to this design from end of 2018, as can be seen in this picture. These two rests and the side stand are not part of the swingarm design, but afterthoughts. At least the foot rest for the driver is now (December 2020) a welded part of the swingarm (where it does not belong).

2.3 First product - v1.0 in Da Nang early 2019

The initial design is finalized. The name changed from Gausscycle to dat.bike. The first step is a rental service for these bikes. The shop opens at 23 Nguyễn Thái Học in Da Nang in early 2019. The intention is to rent the 10 (?) bikes to visiting tourists and give them a chance to have a clean ride around the city [htk2019]. It should be an easy business since electric bikes have almost no maintenance. No oil change, no high temperature from combustion, no exhaust noise. The moving parts can be fixed with sealed bearings and should last a lifetime. Did it work out?

In August 2019 the manufacturing was set up and within a month some 60 bikes were sold. This was revealed in September (still with v1.0 design):

Shark Tank Vietnam - 2019/09/25

This visit gave a lot of details about the company. The 17 minute video [sharktank2019] with more than **1 million views** reveals an estimated production cost of 25 million VND for the bike and 60 sold bikes after 1 month of operation of the company. The worth of the company is estimated at 6 million USD. The suggested retail price is 60 million VND but for early adopters should be reduced to 39 million VND. A later video from October 25, 2019 (with constructive feedback) repeated the price goal of 60 million.

The company already operated in Binh Duong, and had the first v2.0 bikes ready! How do we know?

2.4 Updated Drivetrain - v2.0 in Ho Chi Minh City - October 2019

On October 29th two young men from Ninja Teachers visited the company in Binh Duong, took a test ride and shared their impressions in a video. Obviously both the production place was finished and the first bikes with the new drive train assembled.

The first batch of new produced bikes is delivered in the beginning of 2020, as this video from February 27th, 2020, shows. A batch of **200 bikes** to be finished by January 2020 was planned in 2019, as this report from November 2019 shows [dautu2019].

2.5 The motor

2020/12/04
Some information is provided on the website: https://dat.bike/pages/frequently-asked-questions states 5kW for the motor. If you visit the store in D3 you see QS MOTORS written on it. Typed into aliexpress gives you:

- Probably the original motor for v1.0 3000W PMSM 138 70H $239.00
- Probably the second motor v2.0 3000W 205 50H V3TI $280.50
- Complete back wheel 19inch $354.00 (but dat.bike uses 80/90-17 rear wheel)
- Kit with 2 wheels, controller, display and brakes $924.35
- Just the display $24.74
- Simple kit with motor wheel, controller, handles and display $370.00
- Different drivetrain design for lower unsprung mass $610.00
- A possible future upgrade to 10000 W $588.00
- 17 inch motor with sinodial controller for 120/70-17 wheel $998.00

2.6 The battery

According to the registration the battery has 72V and 29Ah, which gives a capacity of 2.088 kWh (see here). As stated on https://dat.bike/pages/user-manual it should last for 100km when driving with 35 km/h (2h50). The 5 kW of the motor is peak power, the energy consumption when driving 35km/his just be 2088Wh/2.86W = 730W.

2.7 Designed in Vietnam? Made in Vietnam?

Looking at the different parts of the bike with many standardized items, that are used in regular motorcycles as well as other electric bikes one might wonder: Which part is actually uniquely designed in Vietnam? And what parts are manufactured in Vietnam? Let's try a list:

- Fork (made in Vietnam)
    - Front wheel, rim and spokes (70-17 made in Vietnam)
    - Rubber tubeless tire (made in Vietnam)
    - Headlight, speedometer, power switch (made in China)
    - Handles, accelerometer (made in China)
    - Mirror (made in Vietnam)
    - Fender (made in Vietnam, **designed by DatBike**)
    - Disk brake (made in China)
- Frame (made in Vietnam, **designed by DatBike**)
    - Seat (made in Vietnam, **designed by DatBike**)
    - Fender (made in Vietnam, **designed by DatBike**)
    - Rear light, indicator light (made in China)
- Battery Box
    - Aluminum outside cast (made in Vietnam, **designed by DatBike**)
    - Batteries (made in Korea)
    - BMS and charge controller (made in China)
    - BLDS driver 5kW (made in China)
    - IP67 electrical connectors (made in China)
    - Cable harness (made in Vietnam, **designed by DatBike**)

- Swingarm (made in Vietnam, **designed by DatBike**)
    - Rear Wheel, rim and spokes (80-17 made in Vietnam)
    - 3000W QS BLDC motor (made in China)
    - Dual rear suspension (made in Vietnam)
    - Disk brake (made in China)

2.8 Weaver 200 - 27.11.2021

Finally some updates. I had some ideas about what should be fixed a year ago - see 6.1 Fine Tuning And 6.2 Power upgrade. Some things were indeed considered. And we have more media coverage, several youtube videos and so on.

3 Market situation

The following describes the situation in November 2019.

A potential buyer would probably look at similar offerings from other manufacturers. And for positioning the DatBike you have to know the market. In part this was highlighted in this article [24hsongsoanh2020] that mentioned VinFast with Klara, Impes and Ludo as well as Yadea (China), MBIGo (Korea) and Pega (Vietnam). If you are going to spend 40 million, you're going to ask "what's out there?"

DatBike has to face both the large variety and proven reliability of combustion engine bikes and other manufactures of electric bikes. Key advantages over combustion bikes?

- Less noise
- Less pollution (ca. ¼ CO_2 footprint as calculated and published by Son in blog)
- Less maintenance (much simpler mechanic, no carburetor, piston, …)
- Lower fuel costs (3kW output to ride 65km/h consumes 2L/100km for Honda Airblade and with 15000VND/L that's 30000 VND/100km. Electric needs 1.5 hours or 4.5 kWh for 2000 VND/kWh so 9000 VND/100km) 70% cheaper
- Better conscience - you do something for the environment
- Image value - you can show others that you care for the environment
- In some cases better initial acceleration at the traffic light
- Slightly lighter that motorcycles (Honda Winner 122kg 11.5kW, Airblade 110kg 8.4kW, Wave 98kg 5.1kW, Blade 98kg 6.18kW, Super Dream 95kg 4.4kW, Yamaha Sirius 97kg 6.4kW, Mio 91kg 5.8kW, Mio Amore 90kg 6.5kW, Impes 75kg 1.7kW)
- Did I say **status symbol**? This might be the most important reason behind something expensive moving on the street. Think of all the sports cars that could drive 300 km/h in theory, but have not a single road in Vietnam to do so. What if you could show off with a unique electric bike?

To differentiate from other electric bike manufacturer the pitch could be

- Designed and made in Vietnam (because some people don't like China, but VinFast and Pega are Vietnamese as well, yet national pride is strong)
- Highest power (except Pega-S with 3200W sustained) but other foreign manufacturers might soon announce their model in Vietnam like Kymco F9 or Soco TC or Gogoro.
- Lighter than competition (?!)
- Unique design (not a standard scooter like most others, including Gogoro) and not another copy of the X-Men
- Customisation - my color, my seat, my ___
- The last two points are again for the personal image as a value. See status symbol!
- Look really good, so compelling that your inner voice says "I want one!!"

Let's now look at other electric bikes on the market:

3.1 Chinese bikes (Lihaze, Theli and Askmy X3)

China not only produces parts for electric bikes, they build and sell complete ones as well.. There is a store named *Smart Electric Bike* in D7 (http://xediennhapkhaugiasi.com/) that sells several chinese electric bikes with different brand names

- Askmy X3, 250W, 36V battery 8.5 Ah (0.306 kWh) Panasonic 2900PF, max speed 35 km/h
- Theli is like a bicycle, max 45 km/h, range 60km with 15Ah battery (voltage?)
- Lihaze bicycle style as well, 24kg, max 40 km/h

The available information is rather limited, but the models are not a real competition. They are much slower and have less battery capacity. Way less power. It's a different use case.

3.2 Pega Bikes (formerly HK Bikes)

In AEON mall you can buy Pega Bikes (HK bikes) for many years now. Some no-bicycle ebikes are:

- Pega-S 38,900,000 VND with 4 kW motor and 120km range, 2230x1150x750 mm, 155 kg, battery 72V 32Ah 2304 Wh - MAX 65km/h
- NewTech 22,500,000 VND 1.5 kW (2.25 kW max) 72V, 20Ah, 90km range, 1440 Wh max 55km/h
- Aura+ 14,900,000 VND battery 60V 20Ah (1.2kWh) 800W (1.2 kW max)
- X-Men+ 14,900,000 VND 1.2 kW, range 100km, battery 60V 20Ah (1.2 kWh)

Look at the frame from Aura+ on the right and compare it to the frame from Dat Bike.

Situation in December 2020

Pega has **300 locations across Vietnam.** Their largest bike, the Pega-S has more power than the dat.bike, a larger battery, better suspension, more storage capacity (storage at all), more ergonomic seats and for the targeted first 30000 bikes a price reduction to 30.990.000 Dong, which makes it 9.000.000 VND cheaper than the weaver. Just the design is subject to the viewer.

Test drive Pega-S on December 19th, 2020

Stopping by a second time at Cửa Hàng Xe Đạp Điện HK Bike PEGA I used the chance to take a test drive on the 160kg 3.2kW Pega-S. Prior to the ride we had a look at some settings. For example you can switch between Eco and Sports. In Eco your maximum velocity is limited to 50 km/h (even when standing, the rear tire wouldn't spin faster) and in Sport the maximum is 65 km/h. Even though in good conditions you might go up to 75 km/h or even faster downhill. Obviously an electronic limitation and probably related to safety measures regarding the driver, the bike and proper cooling of the motor. But now for the test ride:

This bike is SLOW!!! The acceleration from stand *should* be immediate and powerful, but the software design limits the power output both in time (slowly increasing after pulling the throttle) as well as relative to the velocity (less power at lower velocities to achieve a uniform - but low - acceleration until 65 km/h). You sit on your bike and always wish for more power! **The acceleration is terrible!**

As for the handling and comfort, it is relaxed, even with two people. Handling around small corners is not as easy because of the large wheelbase, but once in motion you don't really recognize it.

Further observations: The 3 pin charging port looks compatible with IEC-60320 C13/C14 "Warmgerätestecker" that is used in Europe with 240V 10A but in this case labeled as 100V 10A. For

the 72V 32Ah battery the minimum charging time with this connector would be 3.2 hours if the 10A would be fully used. In reality the charging time is 8 hours. Idea: Use the SpeaKon connector with 30A and an upgraded charging module and you could fast charge the bike in one hour! And then ride another 100km!

Another observation is the circuit breaker (hello Dat Bike) under the seat. The space there is as wide as Airblade, NVX or Lead, but not very deep. My helmet does not fit in, only a half shell helmet as many uses can be put there. Anyway, the circuit breaker is designed for 100V 60A which gives a "ludicrous mode" power output of P = VA = 72V 60A = 4320W. Guess that would be fine, but my test ride showed that the electronics limits the current to values waayyyy below that.

Price and service: Pega bikes sells the first 30000 bikes for 30,990,000 VND and helps with registration and licence plate for additional 4,000,000 VND. But as a foreigner you need a work contract, a residence card and a work permit. Or you know someone from Vietnam and register on his name.

Companion App: It does not exist yet. But the friendly staff knew about the very concept and declared that it is in development and should be available in 2021.

3.3 Vinfast

And another Vietnamese producer of electric bikes is Vinfast. They started their production in HaiPhong in 2018 and sold 50,000 of them in 2019. In 2020 they plan to sell 112,000. Size of the factory is designed for 250,000 per year.

- Klara S 39,900,000 VND plus 2,400,000 VND rental fee for 2 batteries plus 1,100,000 VND Charger but only a 1.2 kW motor.
- Klara 50,000,000 VND with Lithium, with heavy Acid-lead 30,000,000 VND.
- Impes 14,900,000 VND 1.2 kW (1.7 kW peak) but battery 22 Ah - Voltage?
- Ludo 12,900,000 VND 500 W (1.1 kW peak)

3.4 Dibao

This chinese company sells a variety of electric bikes in Vietnam for around 15,000,000 VND with 1000W motor. **15 locations** in Vietnam, 3 of them in Saigon.

Website: https://dibao.com.vn/ and https://thegioixedien.com.vn/ . "Original" Honda and JVC.

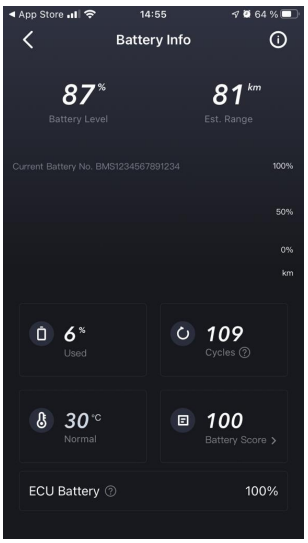
3.5 Niu - in Saigon since 2018

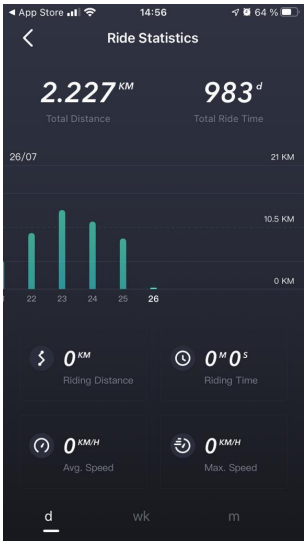
Location in HCMC: 23 Bà Huyện Thanh Quan, Phường 6, Quận 3, Thành phố Hồ Chí Minh

This showroom was opened in 2018. It Does not seem to have a service part, just show and sell. As of December 2020 they only sell the N Sport with 1500W Bosch motor and 60V29Ah 1740Wh battery with 5pin connector both charging and battery (difficult to remove for the two women working in the store). Battery is located in the bottom of the frame at the foot rest and would indicate why the maximum water depth for compatibility for NIU bikes is 27 centimeters. Selling point: 58,000,000 VND.

Quality of the design: successful in China, but the battery handle on two batteries was already broken off. It's traded at the stock market and sold 493,000 bikes in the first 10 months of 2020!

TheBig plus: a large trunk under the seat, almost like Airblade or Lead. Too narrow for my helmet, though :(And the smartphone app wouldn't connect. Right are some screenshots.





This is the Niu NQI GT/S for … look at the inside for the frame. 3kW Bosch motor, 32 sensors, OTA, App, 60V35Ah battery 4200Wh but 3599 Euro. Not sold in Vietnam, not planned for 2021. So far :)

3.6 Soco TX and Soco TX Max

They are not yet on the Vietnamese market. Started in China in 2015 and introduced in Australia in 2019 it's just a question of time until the open in Vietnam. They will then start with a reputation and credibility. And proven products.

OK, the Super Soco TC looks similar to dat.bike, is a little more expensive, but the Max relocates the motor!

2020/12/03 The frame of the Soco TC Max on the left, details of the suspension on the right with the correct mounting points for the foot rest. Split frame design, left black part 6 kg, robot-welded carbon steel. Battery 72V 45Ah 3240Wh. Only 80.5kg without a battery pack.

More details: Soco founded in 2015, expanded to Australia 2019. UK review July 2020, Australia review July 2020, August 2020,

3.7 EVIDA

https://evida.vn/?view=en

Price 49,900,000 VND for a swiss designed bike with 3000W motor and a 72V 35Ah 2520 Wh. The dedicated App is still in development (more than a year now). 68kg without battery.

Showroom: #67, B4 Street, SALA Town, District 2, Ho Chi Minh City, Vietnam

3.8 Yadea - Hong Kong

This company from Hong Kong has been in the market for 20 years and operates now in 70 countries. Produces 6.7 million bikes per year. It has several shops and service centers in Vietnam. Some of their models:

- Xmen Neo 16,590,000 VND 1000W 60V
- YADEA E3 15,990,000 VND 500W for up to 45km/h
- Yadea X5 21,990,000 VND 1200W 72V
- YADEA Ulike 18,990,000 VND 1200W 1440Wh 72V max 50km/h 12 inch
- YADEA BUYE 21,990,000 VND 1.2 kW 72V20Ah 1.44kWh 90/80-R12 90/80-R12

- YADEA G5 39,990,000 VND 1200W 72V 22Ah 1584Wh 26 liter storage under the seat max speed 50km/h, suspension 89mm

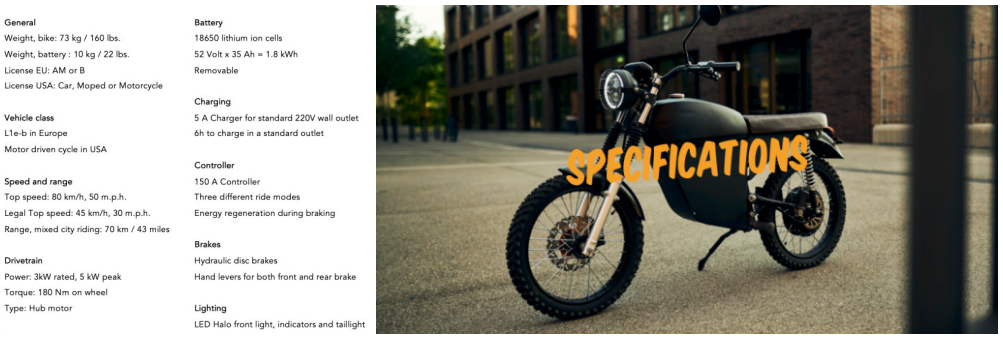
And this company has a working app! The S-Force with 2000W is not yet offered in Vietnam.

Remarks: Shell is ABS plastic, painted 9 layers with Swedish Becker paint PU coating

3.9 International market

3.9.1 Black Tea Motorbike

The BlackTeaMotorbike has a similar design as DatBike and similar specs, but a different price tag (2890 € = 80,917,200 VND). Read their indiegogo campaign.



3.9.2 Tromox

The Tromox Mino looks like a shrunken version of what DatBike v3.0 should be like.

3.9.3 Deco Green Energy

And then there is deco green energy from Thailand. Look at their MaxOne.

3.9.4 Atumobile.co

The company automobile.co offers their Atum 1.0 from India for just 50000 RS = 680 USD = 15,700,000 VND. The design looks similar to Dat Bike, but wider wheels and less power/battery/price

As for India: It's a larger market than Vietnam, wayyy more polluted, but they produce the KTM Duke 200 for example, and many other stronger bikes.

3.10 Kymco Taiwan with F9

Battery 96V 40Ah 3.84kWh, motor 9.4 kW, max 110 km/h, range 120km, 107kg, seat height 790mm. Review video. Battery 17kg, 12.5 HP. Remember: Not available yet. Like 2019 SuperNEX.

No electric bike registered for Kymco in Vietnam yet.

3.11 Gogoro

https://www.gogoro.com/smartscooter/viva/

Costs 1800 dollar, has 3kW motor, 80kg - similar to Dat Bike. But VIVA plus has 10 color options and VIVA has 3 color options. And a synchronized braking system. And 21.6l trunk. But the battery has only 1740Wh. Dedicated App.

3.12 Metacycle by Sondors

https://sondorsx.com/pages/metacycle
Interesting insight in an interview with Micah Toll from electrek.co published January 22nd, 2021.

$5000 for 130 km/h from the 14.5 kW (peak, nominal 8 kW) motor and 4000 Wh battery. R17 tires.

3.13 Fisker

Not really in the motorcycle market, but helps to give an insight to the process. Their prototype is from 2018. Yet no production car in 2021! They acquired $1 billion through a SPAC (Special Purpose Acquisition Company). Because you can easily burn through $100 million in the development phase. They abandoned solid state lithium batteries. And to avoid "**manufacturing hell**" they want to outsource the production to Foxconn or specialist Magna (#3 in the world). More on the Verge interview.

4 Changes in DatBike v3.0

If you look back to the early design stages in California (see 2.1 First prototyping) from April 2018 you notice the design choice for the frame of two tubes: one upper horizontal one and a second bended one below, resembling the well known diamond frame from the 1800s. Strapped to that open space in the frame is the battery, with rubber bands in the case of the prototype.

The first commercial design from November 2018 (see 2.2 Updated design samples - Gausscycle) uses the same design principle, but is only slightly altered. The commercial product in Da Nang from early 2019 makes no changes to the frame. It is missing many details of regular motorcycle frames, even from simple single cradle ones (not to think about perimeter or trellis frames).

This design from the end of 2018 is still sold in 2021 - 2.5 years later. And so far no upgrade in sight. That does not sound like an innovative $6 Million startup. The promised customisation options were actually reduced. From 3 color options in October 2019 the offer is now down to one single product of the company, with just one color.

4.0 Finally got it!

This subheading was introduced long after the following paragraphs were written. Why? Because I finally (December 23rd, 2020) found the direction for Dat Bike 3.0. In a sentence: it is an electric Vario or Vision. How does it look?

It is a scooter, flat footrest, 14 inch wheels, fixed lighting. The electronics are behind these lights - high enough to be protected from flooding. The waterproof sealed batteries can be put under the footrest for a low center of gravity. The suspension itself is changed to twin springs left and right as in the AirBlade, the seat is taken from the airblade as well. This gives a great storage room under the seat.

What led to this rather definite description? It's a result of analysing the market in Vietnam and the limitations when designing a new prototype. The first limitation is that the funds allow one only to develop one new model. I might be upgraded to a candy scooter like the Gogoro later. And different styles might come. But we should start here.

4.0.1 Limitations

It would be great to create a motorcycle with unlimited funds. And that could be sold at any price. In reality there is a budget for R&D. And if your selling point is too high nobody is going to buy your product. And we still want to adhere to our high quality standards. What are our limitations?

- Very limited budget in R&D (update 2020-12-24: I had no clue 😓)
- Not enough experienced designers and engineers in software development, motorcycle frame design, electrical design, exterior design, plastic shell design and production, material science
- The outer shell needs 16 different parts. Injection mold would be extremely expensive, but even suction mold has its price and requires expensive thermoplastics
- The low bottom frame of a scooter puts a lot of tension on the joints and stress on the main tubing. The calculations have to be precise to provide safety
- 2020-12-24: Only one key person trying to do all the stuff. Outsourced partners are not reliable and deliver low quality, but moving everything in house will not solve the problem. It just creates another one.

4.0.2 Solutions

We can take some inspiration from the Mendel project to design a 3D printer for enthusiasts that don't have a budget of thousands of dollars. They designed their prototypes from **"of-the-shelf"-parts**. The development still took years and is ongoing, but with time and enthusiasm they changed the world! How does this apply to us?

We will use **standardized** parts **as much as possible** to keep the costs low. This relates to costs of development and production as well. So we use these standard parts:

- Front fork upside down 80mm like Honda Airblade, rake 25 degrees
- Front wheel 90/80 R14 aluminum cast 5 spokes
- Front disk brake 120mm double cylinder
- Rear wheel R14 with 100 width, aluminum 5 spokes, connector gear left, disk brake right
- Rear disk brake 100mm single cylinder
- Rear tire 100/80 R14
- Seat from Honda Airblade
- Double suspension like Airblade with

Parts to develop

- Frame for low bottom frame
- Fork with mount for motor
- Exterior plastic cover shiels 16 pieces
- Charge controller battery
- Removable battery pack 2kWh
- ECU with CAN and Bluetooth, telemetric data collection
- Bluetooth App iOS and Android

4.0.3 Reality December 2020

A visit on December 24th, 2020 revealed a more dire reality. The battery production was outsourced, but is moved to EIS by end of December 2020 and will be produced in house. What looks like simple spot-welding of Ni-plates to the 18650 batteries proved to be another challenge when it comes to quality and reliability.

A second concern is the BLDC driver. This was another outsourced part that proved to be unreliable. Now the development of a controller is moved in house. This is actually a little more complicated. The VESC controller uses a STM32F4 MCU to drive the mosfets, but the schematics of the board are not available at https://vesc-project.com/ but the software is . The controller has been developed by Benjamin Vedder from Sweden since 2015. It has at least CAN and USB connector and english configuration software. Benjamin stated that the hardware is only 1% and 99% lies in the software, which is now developed by 24 contributors and forked 669 times. It is built on the ChibiOS real time operating system.

The VESC project includes a nice calculator for the electric power train from battery, voltage, current, controller, drag, efficiency and so on to determine specific parameters of an EV vehicle.

4.0.4 Target audience 2020

As of now the Weaver is not positioned to the mass market or competition to Clara, NewTech or Pega-S. Instead its unique design should differentiate this bike (and the driver) from standard average motorbikes. This decision sacrifices practicability to a large degree, even cafe racers include small design parts to improve usability while mainly designed to be a showoff.

4.1 What is the target audience? What product do we want?

For ideas on this bike you have to know your target audience. Let's assume it should continue its distinctive Cafe Racer style and not reflect the practicability of a Scooter. A distinctive feature is the naked design (like roadsters or standards). But it doesn't have a large motor block to draw attention, nor shiny chrome exhaust pipes like easy riders do. So what design elements can we use?

While v2.0 still has many design flaws from these early stages and many of them are unfixable, let's see how a new design should look like and what thoughts should go into this design. One way to define the prospective goal is to compare it to something existing. Honda is the market leader in Vietnam and has a variety of models. Which one is closest to the new Dat Bike?

- Wave 19.280.000 VND
- Blade 18.350.000 VND
- Future 30.190.000 VND
- Vision 29.990.000 VND
- Lead 38.290.000 VND
- Airblade 41.190.000 VND
- Winner X 45.990.000 VND
- Vario 150 51,000,000 VND or Click 150 89.000.000 VND
- SH Mode 125 53.890.000 VND
- CBR150R or CB150R 105.000.000 VND
- Rebel 500 180.000.000 VND

4.2 Frame

A new design

When I started to compile this document in November 2020 I had a lot of ideas and really liked many futuristic and sporty designs. You can still read and see what I discovered back then. One month later I realized that almost all of these ideas are unrealistic. There are 2 main reasons for that.

1. Market in Vietnam

Motorcycles around the world usually have the gas tank between the handlebar and the seat. That's the case for more than 100 years. But Vietnam is different. Initially there were no big bikes, just scooters like the Honda SuperCUB. The many underbones that follow have the gas tank under the seat. You need a high position above the engine to have the gasoline flow to the carburetor by gravity. A pump is expensive, needs maintenance, can break and is heavy. Simplicity is king.

Therefore most motorcycles have the space between the handlebar and the seat empty, either 50% (Blade, Wave, Airblade, NVX) and equipped with several hooks or a shiny silver frame or small seat. Or the bike is scooter style and has a flat bottom (Vision, Lead, Vario, SH). That's the case for **95% of motorbikes** in Vietnam. The new design should reflect this situation, I think.

classic	**underbone**	**scooter**	**western**
			
Blade, Wave, Sirius, Jupiter, Exciter, Winner	Airblade, Nouvo, NVX, Hayate	Vision, Lead, Vario, SH, Click,	CBR150, R15, Duke 200
17 inch	14 inch, 16 inch	14 inch, 12 inch	17 inch

2. Limitations in design, engineering and production

One has to be realistic if you want to compete in a market with much bigger players. With the small production volume and limited financial resources it is simply impossible to recreate the sophisticated solutions of large motorcycle companies. And the quality, experience and skill set of Japanese companies (Honda, Yamaha, Suzuki, Kawasaki) or even Taiwan (Kymco, Sym, Gogoro) cannot be matched.

The local advantage is that GDP and income are lower in Vietnam. This can elevate with cheaper, simpler solutions. China is a big player as well. But the cheaper competition still lacks good design. And the good players there are already too expensive. The niche for Dat Bike is definitely there!

The new design will have some limitations. Designing a complete new exterior body is a massive task and most likely impossible. The mold for some injection forms alone would cost more than 100,000 $ and we would need several! Can we borrow from other designs? For example the seat from the Airblade and create a similar large trunk space? Who produces the frames for bikes locally? What can we learn from them?

Rigidity test of the v2.0 frame

A good thing for the v2.0 frame is that it has been tested and is approved by the Vietnamese authority. Here is a video about the load test: https://youtu.be/kwE7O3fUMjQ . The mass of 300 kg is ok, even

though the bike is only certified for 215kg. But the acceleration is not realistic. And since F=ma the actual testing of tension forces F is not done, since a is too small.

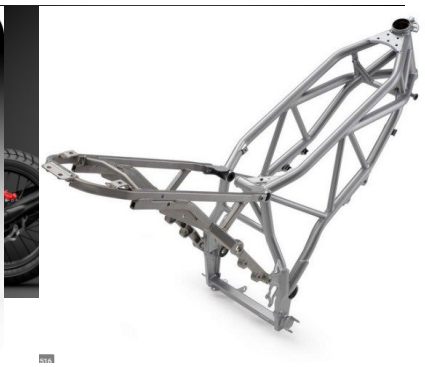
Initial thoughts from November 2020

The frame now consists mainly of two tubes to surround the battery pack and provide connection points between steering fork, drivetrain, seat and battery pack. It is very narrow and in the background with its black color. It looks like its cold-formed tubes, not hydroformed?

Since you don't need a tank, gearbox, carburetor, oil cooler and combustion engine the bike needs less heavy parts.

If it should not have some storage capacity, why not put the battery in a low spot for a lower center of mass and make the empty space a design element? Like this design study on the left?

There is the aesthetics of a space frame used like an exoskeleton, providing great structural stability. Plenty design ideas are out there and many custom bikes use them:


See this article at rideapart about the history of motorcycle frames.

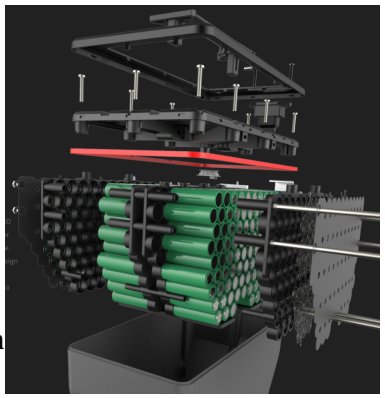
4.3 Battery and electronics box

With 320 batteries 18650, what is the maximum power output? It is in an aluminum box, connectors hidden? Expandable? 6 screwed connection points to the frame - standardized? Box is 15 cm wide, could it be extended to be 22 cm wide for a third layer of battery, improving capacity by 50% and possibly peak power? Seamless integration? Some calculation needed, …

Update 2020/11/30: it's only 200 batteries. 2088 Wh. For comparison: Pega-s 2300Wh, Gogoro old 1374 Wh, new 1740 Wh - 3480 Wh in each bike. But not 18650, instead 21700 like Tesla.

Is OBD (on board diagnostics) integrated? Like charge cycle or battery health? Charge history and capacity estimate? Is an internal I2C bus available? You could connect with an ZS-042 to know the time of the collected data (DS3231M) and store it at the 24C32N. Or store it on an SDcard. Or submit it to the cloud over 2G. Like Gogoro is doing, they use 80 sensors. How many are used in dat.bike?

What about bluetooth connection and a companion app? The fingerprint sensor is more a gimmick. Battery box (removable) from Soco TC MAX:



Hide the wires (electrical and mechanical) somehow in the frame or with other design decisions. Details and images follow. Inspiration from racing bikes from Giant and Cannondale, or delta frames from Yamaha etc.

The foot rest for rider and socius/pillion is both connected to the rear wing! What a design flaw, it shouldn't be unsprung mass! This reduces comfort immediately. Connect it to the sprung mass of the frame, look at solutions from Honda Super Dream 100cc (picture right) from 1995 for example.

4.4 Seat

It is too narrow, not high enough and the used foam is not stiff enough. Calculation (force per area) follows, compression constand (like 2D spring constant) for a more comfortable ride. Measurements 2020/11/28: 57cm long, 13 - 22 cm wide. Less than half the height of Honda Dream or Wave 110 or any other bike. … 2020/11/30 Gogoro spent a big part of the advertisement on the seat quality! Seat position is fairly above the rear wheel. Should be more centered.

4.5 Custom Bike

Since the first bikes were built-to-order, is this a possible niche to fill? With different color options? Custom color choice? With extra cost, but that's customisation and people like uniqueness. Wider tyres? Direct view on rear tyre? The idea was already developed with v1.0 and published October 2019

2020/12/01 The wheels of the dat.bike are rather large and narrow - like a bicycle. 17 inch and 80 wide for the rear. For comparison: Pega-S and Nouvo are 16 inch with 120 and 90 width. Airblade and Kymco F9 have 14 inch tyres, and are 90 and 140 wide.

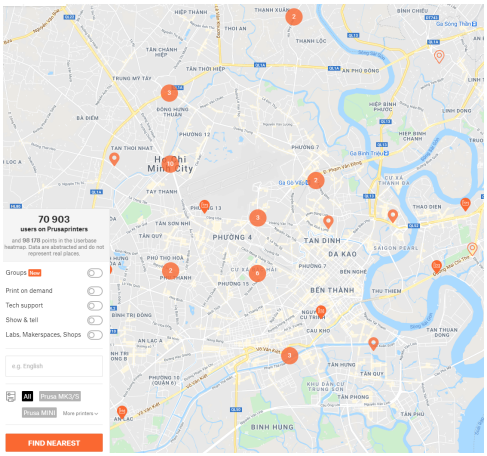
4.6 Regenerative braking

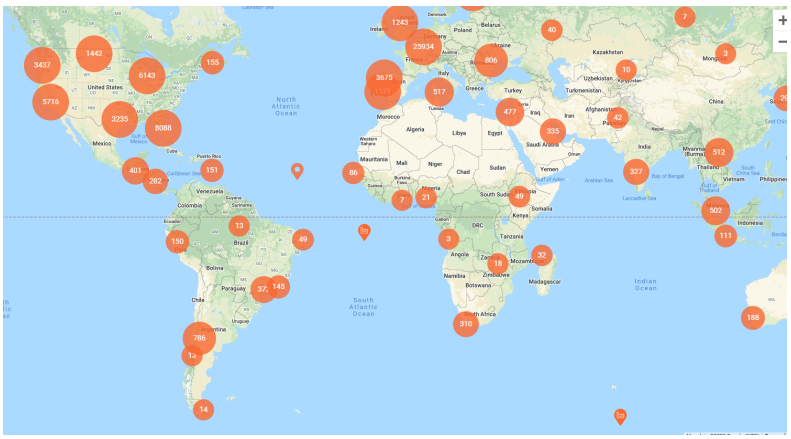
Just a short notice: it is a waste of time. Detailed calculation follows, with work = force times distance, mainly force air resistance (qubic on speed), friction (linear and quadratic) and bearings (mostly constant dynamic). Prediction: Less than 1% improved efficiency or range.

4.7 Website

Usually a startup has pictures of it's members and what they are doing (CEO, marketing, designer) and a little history. It's still missing on dat.bike. Or a little history like https://www.prusa3d.com/about-us/

What about the Dat Bike community like it is seen on prusa3d.com? Look at this map to find someone near you, a group, tech support: https://www.prusaprinters.org/world. Left HCMC, right world





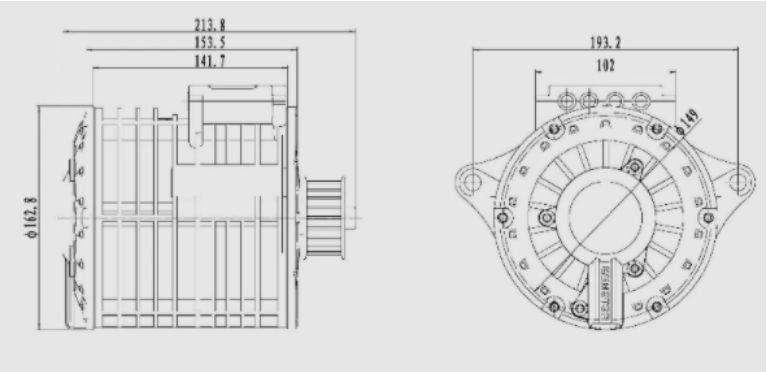
Make part of Dat Bike open source? Share with the community, make parts of the design open source (for enthusiasts that want to upgrade) and a store for the original stuff that just works? Like Prusa does?

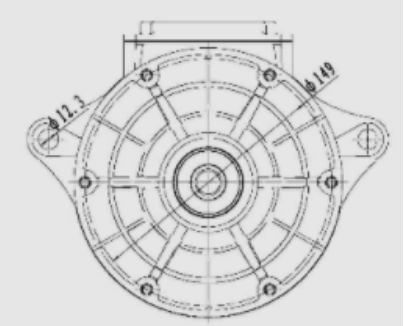
4.8 Drivetrain design - the swingarm

The version v1.0 from 2018 has no entry in the database of http://vr.org.vn/ (yes, I know, not even https. I created certificates myself in 2016 with LetsEncrypt! But I'm just a private person and not a government organisation). Only the dat.bike v2.0 with the motor on the rear wheel axis has a registration frame number RL9C1FNLS?CCA???? (limited to 10000 sold bikes) and an entry without a picture from 2020.

The transmission chain can be changed to maintenance free belt: Gates Poly Chain Carbon El Belt as seen in this video without lubrication. I don't know the correct pitch. But Gogoro is using one. Here in metric units.

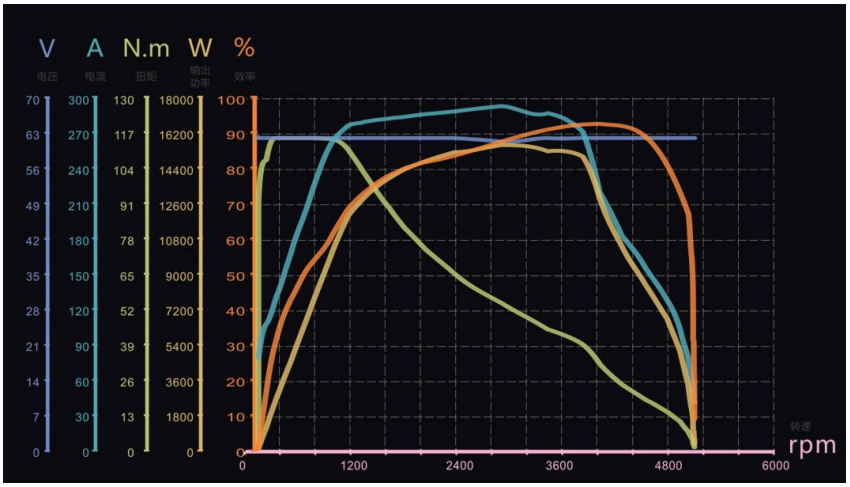
Mid Drive motor width 214 and diameter 163 for 3000W with 1:4.7 gearbox $258





Or from Taiwan? Like from Cyclone? 6kW at 3500rpm. We need a reduction rate of 1:23 for the rear wheel, or 20:460 for the gears! Like in the 18kW Enduro bike.

What about the SUR RON SP180-C1 with 8kW air cooled? And Controller?

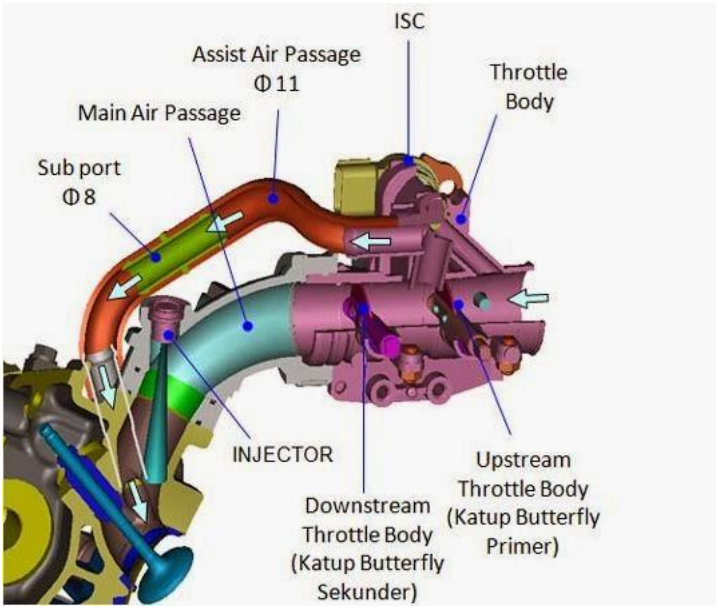


93% efficiency, and 485 connector, plus CAN - latter one recommended. It's 1332 Euro.

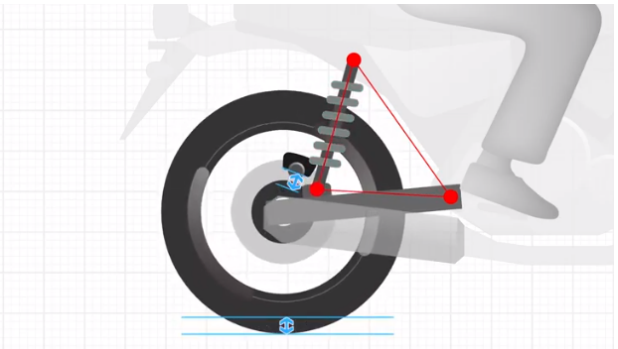
Golden Motor offers 5kW motor BLT-108 for $446 ($320 if you order 10 of them)

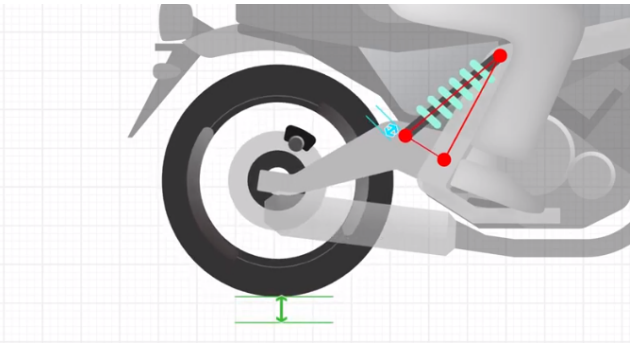
10kW is $765 with pictures of DIY from customers.

As for difficulty: electric bikes are rather simple in their design. Compare this for example to just a small part of the Fuel Injection System JMYET from Yamaha for their small motorcycles:



Since we are already talking Yamaha, let's look at the advantages of the Monocross suspension other than that it looks good:



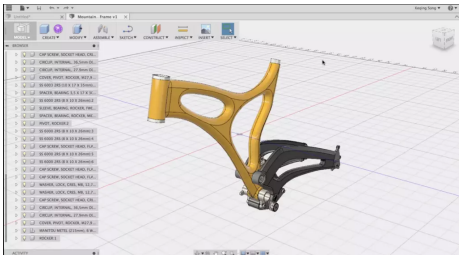


And there is Inverted Front Forks, the Deltabox frame, and even CVT (not relevant here).

4.9 Collaboration with the University

Why not start a design challenge with the students of the university? Give some parameters like wheelbase, 17 inch wheels, rake angle and seat height and let students come up with ideas about how they would design the bike.

Does the university have a workshop? Are there contacts to outside mechanics that could weld the designed frames? How much would a custom-designed frame cost?



With the email account from the university the students could create a free account for Autodesk Fusion 360 and design several designs, combine them, animate them and even simulate the stress in different situations (static stress, non-linear stress, simulations). They could alter the wall thickness of the tubes and probably reduce the weight of the designed frames. A scale down model could be 3D printed for visualization.

Ideas

https://evnerds.com/electric-vehicles/electric-bike/latest-custom-electric-motorcycle-diy-builders-from-instagram/

Final steps in the university require a larger independent work from students like a bachelor paper or a master thesis. And the PhD thesis is a custom for more than 100 years. What are some topics Dat Bike could offer, support and benefit from?

4.9.1 Student designed frame

Using the tools available for free for students they can design a new frame. They discuss the advantages, design choice, and solution properties. For example the type of steel used, material strength, optimal temperature for welding, stress distribution simulation, weight optimization, projected cost, BOM and steps to produce.

With some funding some of these frames could be produced and tested. With more experience in the purchasing department for raw materials, better skilled workers that produce the frame - still reflecting the labor costs in Binh Duong - and the buildup surrounding success stories some students might be willing to start their own business like “BD custom bikes”.

4.9.2 Details of energy efficiency on a motorcycle

High Speed road bikes have a very narrow profile to reduce the resistance. And run on high pressure of circa 4-7 bar. But that’s the case for the comparatively lower velocity and power of a bicycle. How much does a wider tire (that does look better on a motorcycle!!) affect the fuel consumption? How much is the effect of driving with the wrong pressure (as 90% in Vietnam do since nobody ever checks the air pressure in the tire, knows that there are recommended values by the manufacturer or even has a pressure gauge).

For further investigation there is a “science test bike” from Dat Bike, equipped with a data logger, power meter, cruise control and other equipment to determine the “real drive emissions” or “energy consumption” and how various design changes have an impact on the required power. What’s the effect of a lower average speed? How much does speed at all affect the power needed to overcome drag? Once we have the data we can start an informed decision.

4.9.3 Investigation into drive patterns

Modern FI bikes, even the semi automatic ones, have an onboard ECU with the CAN bus. We can connect a data logger to the 3 pins (plus, minus, data) and collect speed, fuel consumption, gear and other metadata to create a driver profile for an average Vietnamese person.

The student project could involve to design, solder and program such a data logger and then find 25 average people that agree to have their driving pattern logged. The data itself can be anonymized and stored without GPS. Once this design is done and the data collection successful started it can be expended and give an overview:

- What is the average driving speed?
- What is the maximum speed?
- How much of the time is spent in a specific speed range, like 5-10 km/h?
- How long is the idle time per user on average?
- What are the differences for male/female drivers? Young and old? Commuters and merchants? Office workers and construction people?

The findings can help to tailor new Dat Bike designs to local needs.

4.9.4 Motor drivers, Programming and Efficiency

The EIU has several rooms for electric power generation and electronic control. Collaboration with the scientific staff at the university can lower the burden and incite new ideas. Again: What about a bachelor's work related to BLDC drivers? Or a master thesis about electric design in VESC 6.0 in KiCAD and ordering at JLCPCB? Could it be done locally? Ordered at thegioipcb?

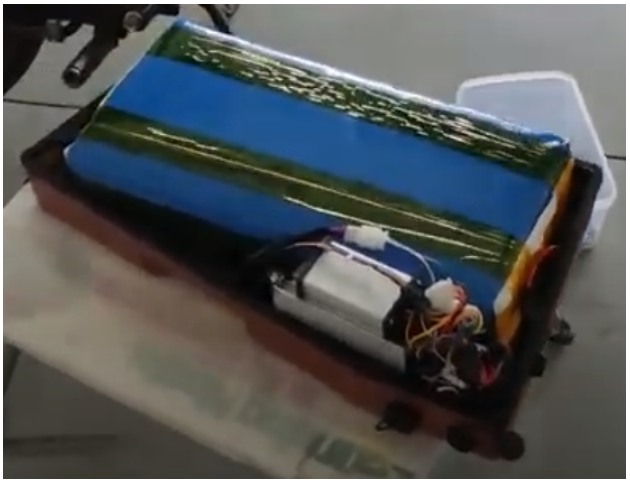
5 Investigations and Calculations

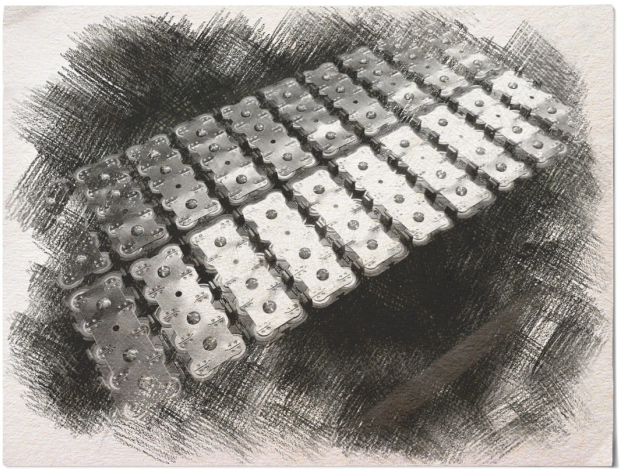
5.1 Battery capacity and structure in the weaver

According to the registration the battery has 72V and 29Ah, which gives a capacity of 2.088 kWh (see here). As stated on https://dat.bike/pages/user-manual it should last for 100km when driving with 35 km/h (2h50). The 5 kW of the motor is peak power, the energy consumption in this case would just be 2088/2.86=730W.

For comparison: The Pega-S has a 2.3kWh battery that should last 120km (3h26). Power: 670W. The sustained power output from the Bosch motor is 3200W and the price is 30.990.000 VND.

With a voltage of 72 Volt there must be 20 standard LiIon batteries of 3.6 Volt in series to generate this voltage. With 10 batteries of 2900 mAh capacity in parallel we would reach the published 29Ah.





On the left side we can see the inside of the battery pack, but can only estimate the amount of cells. That the 10 cells 18650 is correct can be seen on the picture in the website in the background of the LiIon battery: You see 20 packs of 10 spot-welded 18650 batteries!

The charge of the battery is determined by the voltage, leading to each battery (with BMS):

Voltage Battery	82 V	78 V	75 V	71 V	68 V	61 V
Percentage charged	100 %	80 %	60 %	40 %	20 %	0 %
Each battery voltage	4.1 V	3.9 V	3.75 V	3.55 V	3.40 V	3.05 V

One observation in the left picture is that all electronic parts (charge controller, BMS and BLDC controller) are in the same box as the battery. Except for the BMS that's not a good idea. Future designs should separate them and include an easy accessible circuit breaker for safety.

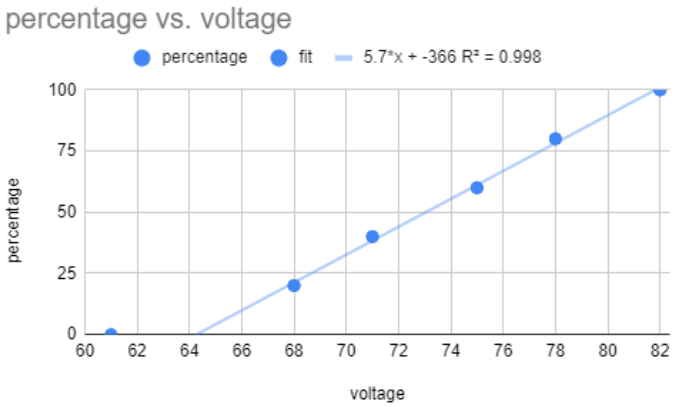
What about mass and dimensions? Some cheaper "Panasonic 4200mAh" batteries have actually only 750maH and a weight of 30 gram. A proper 2900mAh NCR18650B MH12210 has a mass of 45 gramm and stores 3.6V * 2900mAh = 10440mWh = 10.44Wh. The energy-to-mass-ratio is accordingly 4.31g/Wh.

If we only take the cells into account, the battery of the weaver has a mass of 200*45g=9000g=9kg. With Ni connector, wires, spacer, frame, shock absorbing foam and BMS it should be 13kg.

For comparison: The Kymco F9 has a 3.84kWh battery with a mass of 17kg. This gives an energy-to-mass-ratio of 17kg/3.84kWh=4.43g/Wh.

How long will the battery last? In this video Nguyên 7749 Official tests his Weaver from 1.9km with 79.2V Full battery (5 blocks ⬛⬛⬛⬛⬛) to 37.9km with 73.9V (3 blocks ⬛⬛⬛⬜⬜). That's 36 kilometer with 40% battery. Aligns with the claim.

For fun I started a little calculation with linear regression. The correlation voltage - charge is not linear, but for 20% to 100% the deviation is minimal. I got the relation percentage = 5.7 * voltage - 366. Why the negative value? For a percentage of 0% you still would need 366/5.7 = 64 Volt.



Applied to the video from Nguyên 7749 we get 79.2V relates to 85.4% and 73.9 Volt to 55.2%. He lost 30.2% while driving 36 kilometer.
Again within range of the 100km claim for the Weaver.

5.2 Acceleration promise of DatBike

The official data for DatBike state both at vr.org.vn as well as the website 5kW power and 85kg weight.

If it has a dry mass of 85kg and the driver has 65kg and the motor has 5kW we can calculate the time to accelerate to 50 km/h with a given efficiency of 90% (drag, air resistance, friction): $E = ½ mv^2 = Pt$.
m = 150kg; v = 50km/h = 13.9m/s; E = 14467 J.
P = 5000 W = 5000 Js but $P_{eff} = P * 90\% = 4500$ Js
$T = E/P_{eff} = 14467/4500 = 3.2$ seconds
Which means, if the 5kW number is correct, you can accelerate to 50km/h in 3.2 seconds.

How far would you have traveled? $s = v_0t + ½ at^2 = 0t + ½(13.9m/s / 3.2s) (3.3)^2 = ½ 13.9 3.2 = 22.24m$

Simple test: measure the distance of 22.24 meter and stop the time (maybe 30fps video) for the time to accelerate from rest through this distance. BTW: $a = 4.34 m/s^2 = 0.44G$

5.3 Limitations to the maximum speed related to motor power

Now that we know the battery capacity we can estimate the mechanical friction inside the bike and the drag combined in a polynomial fit with 3 measurement points. We are looking for the needed power for a certain velocity: f(x) = P(v) = ax3 + bx2 +cx + d. Since we need no power if we stand (one of the first simplifications here) d = 0. Now we need two more velocity points.

The **first velocity** point is 65 km/h which is the maximum velocity of the bike where all drag and friction forces match the forward pushing force created by the motor. Here we take 3000W as a power value instead of the maximum value of 5000W published, because I doubt that the motor can generate this amount of mechanical energy sustained without overheating at an ambient temperature of 32 °C, a

temperature any good day in HCM easily reaches. Battery, BMS and ESC should not be temperature limited. The manufacturer of the motor labels it at 3000W with peak 5000W. Mass: 15kg.

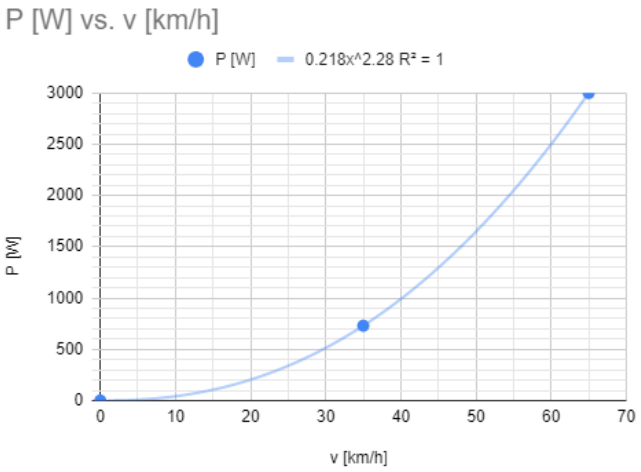
The **second velocity** is 35 km/h which is the given velocity to reach 100km with the battery capacity of 2088 Wh. Here it's a little more precise: To drive 100km with 35 km/h needs 2.85 hours. The battery would be depleted, so the trip needs 2088 Wh or 730W per hour. Let's take this power as a second point. The calculation.

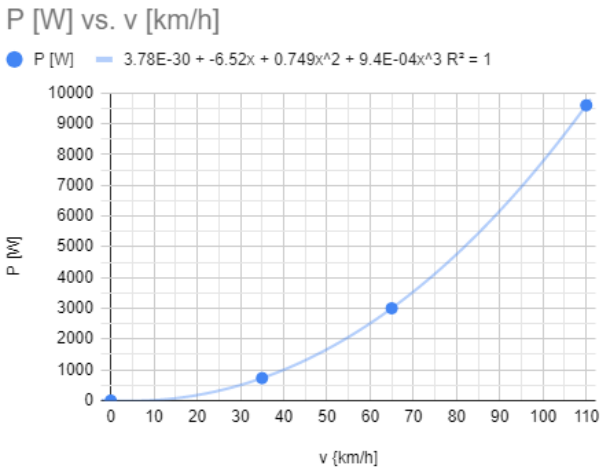
v [km/h]	0	10	20	30	40	50	60	70	80	90	100	110
P [W]	0	120	280	550	1000	1600	2500	3500	4700	6100	7800	9600

First fit: $P = 0.0091\ v^3 - 0.065\ v^2 + 12v$

Second fit: $P = 0.00094\ v^3 + 0.749\ v^2 + -6.5v$

(added third velocity 110 km/h from Kymco F9 9.6kW motor)





The graph shows that you need slightly more than 7.5kW to reach 100 km/h. The Yamaha Nouvo5 delivered 7.8 kW out of 125 cm^3. This puts the claim that the Weaver can take on a bike with 150 cm^3 into perspective.

Look at the values in the table. Most 110cc bikes in Vietnam have more than 6 kW, this should be good for 90km/h. With heat restricting the maximum power of Dat Bike to 3kW over a longer period of time the maximum cruise speed is only 65km/h. For a short period of time up to 80 should be possible, but the heat protection circuit should lower the power delivery to the motor.

[Update 2021/12/16 The Weaver 200 actually has 6kW and 90 km/h - my calculation from 2019 was correct!]

Third simple fit: $P = av^3$ gives the values a = 0.01 - mostly in velocity range 40 - 80 km/h.

Side note: Compare available energy for a short period of time is not a good method. Iron core electromagnets create magnetic fields of up to 2 Tesla. Superconducting magnets reach 10 to 20 Tesla. Bitter electromagnets manage 45 Tesla. Yet my office at the Humboldt Universität zu Berlin was above the "Megagauss" laboratory: They created 311 Tesla in 2004. It's not difficult to predict how they did it.

5.4 Friction forces

We can use these power values to calculate the friction force at each speed. For constant speed the engine has to overcome this force. Since the force is parallel to the direction of motion it has to work according W = Fs. Without a motor the friction will bring the bike eventually to stand. Regenerative braking would only increase this force and lower the distance and time to stop.

Let's just take the 50 km/h value and a bike with 85+65=150kg. The kinetic energy is then E_{kin}=½ mv^2 = 0.5 * 150 * (50 / 3.6)^2 = 14467 J = 14467 Ws. The needed power to overcome the friction is 1600W. With 50km/h = 50/3.6 m/s = 13.9 m/s the bike travels 13.9 meter every second. And since 1W = 1J/s the motor consumes 1600 J every second or every 13.9m. Rearranged the force equals the power over distance or F = W/s = 1600 J/13.9m = 1600 Nm/13..9m = 115 N.

If this force were constant it would take s = W/F = E_{kin}/F = 14467 J / 115 N = 126 meter.

BTW: Gogoro displays up to 6.8kW acceleration and only 0.8kW regenerative braking if you use their app. That is a good indication that regenerative braking does not have a big impact.

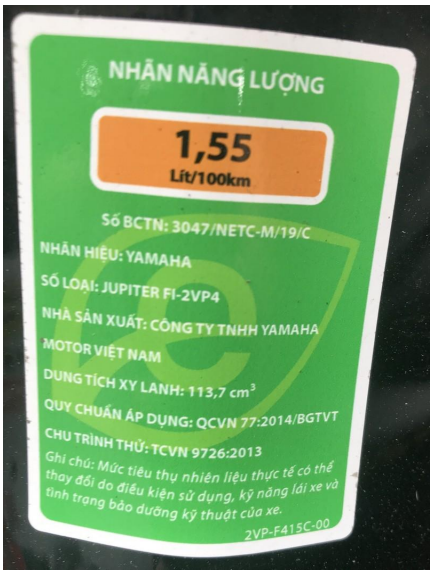
5.5 Can you save money with an electric motorcycle in the long run?

I got my Nouvo 3 2B56 (B56-012910 from 2007) in 2017 for 7,000,000 VND. A Weaver is 39,000,000 VND, some 32,000,000 VND more expensive. I need 2.5L per 100km (it's an old bike, but has 6.42kW and easily outpaces the Weaver with just 113.7 cm^3) and with 15000 VND/L that's 37500 VND/100km. For 32,000,000 VND I could therefore drive 85,333 kilometers.

But the difference is even bigger, since electricity has some costs as well. The Airblade comparison under Market Situation estimates 30000 VND/100km for gasoline and 9000 VND/100km for electric. Every 100 kilometer I save 21000 VND. Let's take a new Yanus with 125 cm^3 for 30,000,000 VND as comparison. You have to drive 9,000,000/21000*100 = 42857 kilometers until the weaver saves cost on consumption.

For my Nouvo: 152,381 Kilometer. Not sure if either of these bikes will last that long.

Now some updated consumption values with fuel injection, here from Yamaha Sirius, Jupiter and Exciter. The sticker on new bikes states:



Or in a table:

	Engine	Power	Consumption	Mass	Wheelbase	Price
Bike	cm^3	kW	L/100km	kg	mm	VND
Jupiter	113.8	7.4	1.55	103	1240	34,000,000
Sirius	113.8	6.4	1.57	99	1235	27,000,000
Winner X	149.1	11.5	1.70	124	1278	45,990,000
Exciter	149.8	11.3	2.00	115	1290	53,000,000
Airblade	149.3	9.64	2.17	113	1286	41,190,000

Results are established by NETC (TT THỬ NGHIỆM KHÍ THẢI PHƯƠNG TIỆN GTCGĐB - Vehicle Emission Test Center)

5.6 Maximum power output from the battery

What is the peak power output of this battery? Can we upgrade the motor to 5kW (8kW peak) while keeping the same battery?

Brand	Model	Capacity (mAh)	Discharge Rating - CDR
MXJO	IMR3500	3500mAh	11A
Efest	IMR18650V1	3500mAh	10A
LG	MJ1	3500mAh	10A
Sanyo	NCR18650GA	3500mAh	10A
Samsung	35E	3500mAh	08A
Panasonic	NCR18650B	3400mAh	05A
Imren	IMR3200	3200mAh	15A
LG	MH1	3200mAh	10A
Efest	IMR18650V1	3100mAh	10A
Efest	IMR18650V1	3000mAh	20A
Imren	IMR3000	3000mAh	20A
LG	HG2	3000mAh	20A
MXJO	IMR3000	3000mAh	20A
Vapcell	INR3000	3000mAh	20A
Samsung	30Q	3000mAh	15A
Sony	VTC6	3000mAh	15A
Panasonic	NCR18650PF	2900mAh	10A
Efest	IMR18650V1	2600mAh	25A
Sony	VTC5A	2600mAh	25A
Sanyo	UR18650NSX	2600mAh	20A
Sony	VTC5	2600mAh	20A
Samsung	26F	2600mAh	15A
Efest	IMR18650V1	2500mAh	20A
LG	HE2	2500mAh	20A
LG	HE4	2500mAh	20A
Samsung	25R	2500mAh	20A
Sony	VTC4	2100mAh	30A
Vapcell	INR2000	2000mAh	38A
LG	HD2	2000mAh	25A
Samsung	20R	2000mAh	22A
LG	HB2	1500mAh	30A
LG	HB6	1500mAh	30A
Sony	VTC3	1500mAh	30A

Brand	Model	Capacity (mAh)	Discharge Rating - CDR
Vapcell	INR2000	2000mAh	38A
LG	HB2	1500mAh	30A
LG	HB6	1500mAh	30A
Sony	VTC3	1500mAh	30A
Sony	VTC4	2100mAh	30A
LG	HD2	2000mAh	25A
Efest	IMR18650V1	2600mAh	25A
Sony	VTC5A	2600mAh	25A
Samsung	20R	2000mAh	22A
Efest	IMR18650V1	2500mAh	20A
LG	HE2	2500mAh	20A
LG	HE4	2500mAh	20A
Samsung	25R	2500mAh	20A
Sanyo	UR18650NSX	2600mAh	20A
Sony	VTC5	2600mAh	20A
Efest	IMR18650V1	3000mAh	20A
Imren	IMR3000	3000mAh	20A
LG	HG2	3000mAh	20A
MXJO	IMR3000	3000mAh	20A
Vapcell	INR3000	3000mAh	20A
Samsung	30Q	3000mAh	15A
Sony	VTC6	3000mAh	15A
Imren	IMR3200	3200mAh	15A
Samsung	26F	2600mAh	15A
MXJO	IMR3500	3500mAh	11A
Panasonic	NCR18650PF	2900mAh	10A
Efest	IMR18650V1	3100mAh	10A
LG	MH1	3200mAh	10A
Efest	IMR18650V1	3500mAh	10A
LG	MJ1	3500mAh	10A
Sanyo	NCR18650GA	3500mAh	10A
Samsung	35E	3500mAh	08A
Panasonic	NCR18650B	3400mAh	05A

Battery type: We don't know the company (LG, Samsung, Panasonic) nor the type (BD? BE? VTC4? 25R? NMC? LMO? LCO? LFP? NCA? IFR? ICR?) And there are many different types available:

For the peak power of 5 kW at 72V the current of the parallel strings would be 69.4A. We can safely assume that the battery uses something like the Panasonic NCR18650PF with 2900 mAh capacity and peak current of 10A. 10 strings combine 200 batteries to have a battery pack of 72V 29Ah. Each string provides 10A max, so the max current of this pack is 100A. Not sure about the resistance of the wires I've seen used at the Weaver and the power loss there. But we get a peak power for the battery of 7.2kW. Good for the 5kW max of the current motor, not enough for the 8kW motor.

But if we change the battery type to Sony VTC5A we lose 10.3% battery capacity (2600 mAh) but the peak current jumps to 25A per string or 250A for the battery pack. Peak output power (short time "ludicrous mode" drag race acceleration) would be **18kW** or 24.5 PS! The 2020 Yamaha Exciter 150 has only 11.3kW (15.4PS). Quite a difference in acceleration!

5.7 Decreasing battery prices - $100/kWh?

A standard 18650 battery with 2600 mAh costs 44.000 VND. Our battery pack of 200 batteries would therefore sum up to 8,800,000 VND. Bulk purchases would get some discount. With 1 USD = 23200 this battery has a price of 182 $/kWh just the raw material.

In 2010 car manufacturers calculated the cost for one kWh at 1037 €. This dropped to 160 € in 2018 and 140 € in 2019 for the complete system including BMS (battery management system) according to BloombergNEF. Reuters reported in 2020 the price for battery packs with CATL's cobalt-free lithium iron phosphate battery packs has fallen below $80 per kilowatt-hour, with the cost of the battery cells dropping below $60/kWh.

Report from electrek.co from December 16th, 2020: Electric vehicle battery cost officially dips under $100/kWh price point! And Tesla is going for LFP batteries.

5.8 Is Design really important? Even more than the raw power?

There are many electric bikes out there with a 250W rear motor. A plethora of companies. Yet at the beginning of 2020 the guys from FLX Bike started a campaign at indiegogo with invisible wires and batteries, called Babymaker. You notice the motor only if you know it. The funding goal: 20000$.

The result: **13,573,396$** or 67869%. Almost 700x more than anticipated. Two power options, 6 colors, 2 sizes, 4 extra options. That's 24 different bike types. Give people what they want. BTW: It is the most successful campaign on indiegogo ever.

5.9 Design inspirations

5.9.1 Thắng Đỗ after Shark Tank, October 2019

Just 2 weeks after the Shark Tank Vietnam broadcast aired and got more than 1.1 million views on Youtube alone a user Thắng Đỗ created a model in 3D software and uploaded his design to YouTube! https://youtu.be/2es3HRyrMzY . Yes, it would not work, the rear suspension is designed wrongly, it reflects more a designer than a mechanic or structural engineer, but the direction is there!

What inspiration can be taken from here? Wider tires, central suspension for the swing arm, seat position a little more to the front, as well as foot rest.

5.9.2 James Biggar from New Brunswick, November 2020

James Biggar in New Brunswick, Ontario, Canada built a beautiful electric bike for fun and spent a decent amount of time on the frame, optics and set. He made a 30 minutes video.

- Time to build: 2-4 weeks
- Video published November 2020
- Price: $4500 CAD for 12kW motor, 24kW peak! That's 3480 USD.
- Details and files: https://www.resystech.com/electric-streetfighter.html

5.9.3 Pham Vu in June 2020

Look at the design study from a vietnamese student to the right. He only has a 2 kW motor and used several parts from other bikes, but the details are great! He designed a central suspension for his frame and the bike looks stunning!

Software used: Autodesk Inventor
Time to built: 6 months

Result: Got several job offerings!

A short report about this design.

Video on Youtube from June 2020.

5.10 Relation of unsprung mass and driving comfort

The following investigation is not new. In May 2019 Leonardo Frizziero published *Design for Six Sigma [DFSS] Applied to a New Eco-Motorbike* [mdpi2019] and did similar calculations.

Version v1.0 of DatBike had the heavy motor (12kg with internal planetary gearbox?) fixed to the frame and therefore part of the sprung mass with higher comfort, but more mechanical parts that needed maintenance like the chain. The new design has it concentrated on the axis. Khoa wrote in his IA that the relationship between riding comfort (e.g. wheel in the air, no contact to the ground) and unsprung mass is roughly proportional to the square root. Unfortunately his explanation of how he deducted this relationship is not consistent and lacks major details. Not sure if someone else would understand it. Following his hypothesis a reduction in unsprung mass by 50% would increase the riding comfort by 29% (with 1-sqrt(50%)). I think the effect is larger.

The estimations and hypothesis on October 13th, 2019 were done without actual masses. But for the Weaver we can use given values. The registration authority states that the weight distribution for the 85 kg bike is 35/50 kg. We can therefore focus on the rear axis and a total weight of 50kg. For gravitational acceleration we use 9.81 m/s^2. But how much of this mass is unsprung?

The QS Motor 205 50H V3 has a mass of 14.5 kg. We add 2kg for the 17" rim, 1kg for the 36 spokes and 2.9kg for the 80/90-17 Michelin (Metzler?) tire. The rear wing might have 5kg, but is on one side fixed on the sprung mass. If the center of mass is estimated in the middle then it only moves 50% of the unsprung mass, we can therefore calculate it as a 2.5kg unsprung mass. This leaves us a total of 14.5+2+1+2.9+2.5 = 22.9kg. For the bike part remains 50-22.9=27.1kg sprung mass.

If we move the motor out of the rear axes closer to the moving point of the wing, let's say ⅔ or 67%. The QS 138 3000W 72V is lighter too with just 11.5kg. Reduced by 67% it only contributes with 3.8kg. The unsprung mass is therefore 3.8+2+1+2.9+2.5 = 12.2kg. Thats only 53% of the current design, 47% less unsprung mass! What is the effect?

While riding with 36 km/h or 10 m/s the wheel comes in contact with an uneven part of the street, for example a 10 mm rock. Simple trigonometry tells that the distance from touching the 17" wheel (432mm diameter) until it is vertically under the axis has a distance of 65 mm (GeoGebra construction with update). With 10 m/s this takes t = s/v = 0.065 / 10 = 6.5ms. The wheel moves in this time 1cm upwards with a speed of v = s / t = 0.01 m/ 0.0065 s = 1.5 m/s. This initial scenario is equal for both cases with current design and improved design.

For this impact we only consider the vertical movement of the unsprung mass (superposition principle). The initial velocity is v_0 = 1.5 m/s, the unsprung mass is m_1 = 22.9 kg and the force is a combination of $F_G = m_1 g$ and the force exerted by the spring $F_S = m_2 g$ from the sprung mass m_2 = 27.1kg. These forces combine to $F = F_G + F_S = m_1 g + m_2 g = (m_1 + m_2)g$ = 22.9kg + 27.1kg)9.81 m/s^2. This leads to an acceleration of the wheel of $a = F/m = (m_1 + m_2)g / m_1$ = 50/22.9g = 2.18g = 21.4 m/s^2 . We use this acceleration to calculate the maximum height the wheel "jumps" and the time it is in the air. Of course this is an oversimplification since the exerted force from the spring will increase with its compression, but we address this later. The fitting SUVAT formulas are (1) $\mathbf{v^2 = u^2 + 2as}$ for the height and (2) $\mathbf{s = vt + ½ at^2}$ for the time. (1) simplifies to $\mathbf{s = -2u^2/a}$ since the final velocity at the highest point is v = 0. And for (2) the distance traveled is zero when it returns to the tarmac. We can then divide by the time t and rearrange to $\mathbf{t = -2v/a}$. We get positive values in both cases since the acceleration is negative. Result: (1) h = 2 * (1.5)^2 / 21.4 = 0.21m and (2) t = 2 * 1.5 / 21.4 = 0.14 s

A jump of 21 centimeter is something the rider would certainly feel. The rubber of the tire reduces, the suspension takes part of it and there is 2cm foam on the seat left. Let's compare to the upgraded drive train. Total mass of 50kg is unchanged, but the acceleration is now $a = (m_1 + m_2)g / m_1$ = 50/12.2g = 4.10g = 40.2 m/s^2 . And we get (1) h = 2 * (1.5)^2 / 40.2 = 0.11m and (2) t = 2 * 1.5 / 40.2 = 0.07 s. The reduction in jump and airtime is proportional to the weight reduction of the unsprung mass, almost 50%! One can imagine how much better the ride over the same street with the same diameter of wheels and the same weight of the bike will be if the wheel only elongates 11cm instead of 22cm. And only for half the time. This might be completely absorbed by the suspension and the seat, you don't even feel it.

In short: An uneven part on the road, 1cm high:

- Current drive train: jump 21cm 0.14 seconds in the air
- Improved drive train: jump 11cm 0,07 seconds in the air

If the rear wheel has a maximum upward limit of 22 centimeters from its center point we can use this height to determine the spring constant. Completely compressed it should hold the maximum load of 215kg, where the empty bike is 85kg. The rear gets 50kg or 59% of all load, so the maximum load for

the rear is 126kg. There should be a safety margin of at least 2cm. The spring would then compress by 20cm if we change the rear load from 50kg to 126kg, an increase of 76kg or 746 Newton. The spring constant from F = Ds is then D = F/s = 746 N / 0.2m = 3730 N/m. This would be 3.7 N/mm - but divided by two because we have two springs, so less than 2 N/mm. In reality these springs have more 13 N/mm to 18 N/mm.

Let's insert some actual values of spring constants.

For our desired monoshock the travel (stroke) will be smaller while the force will be larger an twice since its not distributed on both sides. Example values: Öhlings YA 761 has 240 N/mm and 30mm stroke at 198 mounting length. Max force therefore 240x30 = 7200N or ca. 720kg.

The calculated force F_S for the current drive train is then at the highest point no longer $F_S = m_2g$ but $F_S = m_2g + 746$ N. The total force there is then $F_{top} = 50kg * 9.81\ m/s^2 + 746N = 491\ N + 746\ N = 1237\ N$. More than twice the force from neutral. The acceleration there would be $a = F/m = 1237N/22.9kg = 54\ m/s^2$. This reduces all values above mentioned. You still feel the higher impact from the almost double kinetic energy of the unsprung mass that has to be absorbed, stored in spring energy and released back to the wheel. Part of this energy makes it to your back, you feel it. And you describe your ride as "not very comfortable". Guess why all major electric bike manufacturers (Gogoro, Zero bikes, Kymco, Pega, Harley Davidson, unu, Vespa) move the motor away from the rear axis for real motorbikes, not bicycle replacements.

How far is the suspension travelling? Here some quick data I found: Honda Vision 110 from 2019, front travel 70mm, rear travel 80mm.

Example for a progressive spring: YSS 46-13-18-200 with inner diameter 46mm, spring rate 1 13Nm, spring rate 2 18Nm and length 200mm

5.11 Refined calculation of the effect of unsprung mass

We use a simplified FEM (finite element method) simulation for the impact of increased mass on the riding comport. The modellation can be done in Python, and with Jupyter Notebook this can easily be done online as well, for example with Google Laboratory.

The inspiration for this code is taken from the Wikipedia article for Projectile motion, subheading numerical solution.

Here is the link to the notebook.

And the graph.

5.12 Limitation of maximum motor power to temperature and cooling

Second side note: QS motors states an efficiency of the BLDC QS205 50H V2 of 88%. At 5000W this would generate 600W. The housing of the motor has a diameter of 244 mm and width of 100mm. This gives an surface area of $A = 2\pi r^2 + w\pi d = 2\pi 122^2 + 100\pi 244 = 93518 + 76655 = 1702\ cm^2 = 0.17 m^2$.

Without air cooling the motor would, according to the Stefan–Boltzmann law and with a radiant exitance j*:

$$j^* = \sigma T^4$$

Here the Stefan–Boltzmann constant σ has a value of σ = 5.670373 * 10^{-8}Wm^{-2}K^{-4}. If we multiply the radiant exitance with the surface area we get the thermal power loss at 600W. From P = Aj* = AεσT^4 we transform the formula and calculate the temperature

$$T = \sqrt[4]{P/A\varepsilon\sigma} = \sqrt[4]{600/0.17 \cdot 5.67 \cdot 10^{8}} = 499\ \mathrm{K}$$

We have to remember that the neodymium permanent magnets have a Curie temperature of only 310-400 °C. If the motor gets too hot they could easily lose their magnetisation and the motor would be damaged permanently.

5.13 DIY Battery

Can you build a 72V battery with 29Wh by yourself? Let's look at some YouTube videos, some with more than 1 million views and dating back to 2018. And yes, the first one is German :)

- GreatScott: EBike Battery Pack || Electric Bike Conversion 1,687,767 views • Apr 29, 2018
- EbikeSchool.com: DIY electric motorcycle 72V battery build 351,819 views • Dec 23, 2019
- LithiumSolar: Building 3.5kWh DIY Solar Generator for $650 3,193,646 views • May 16, 2020

Size of the pack, simplification of 18650 battery as 18x18x65 in a 10x20 grid

- Height h = 65 mm
- Width w = 10x18 = 180 mm
- Length l = 20x18 = 360 mm
- V = h⋅w⋅ l = 65 x 180 x 360 = 4,212,000 = 4212 cm^3 = 4.2 liter for 2088 Wh

Upgrade v3.0 should have maybe two possible battery packs attached, regularly sold with just one.

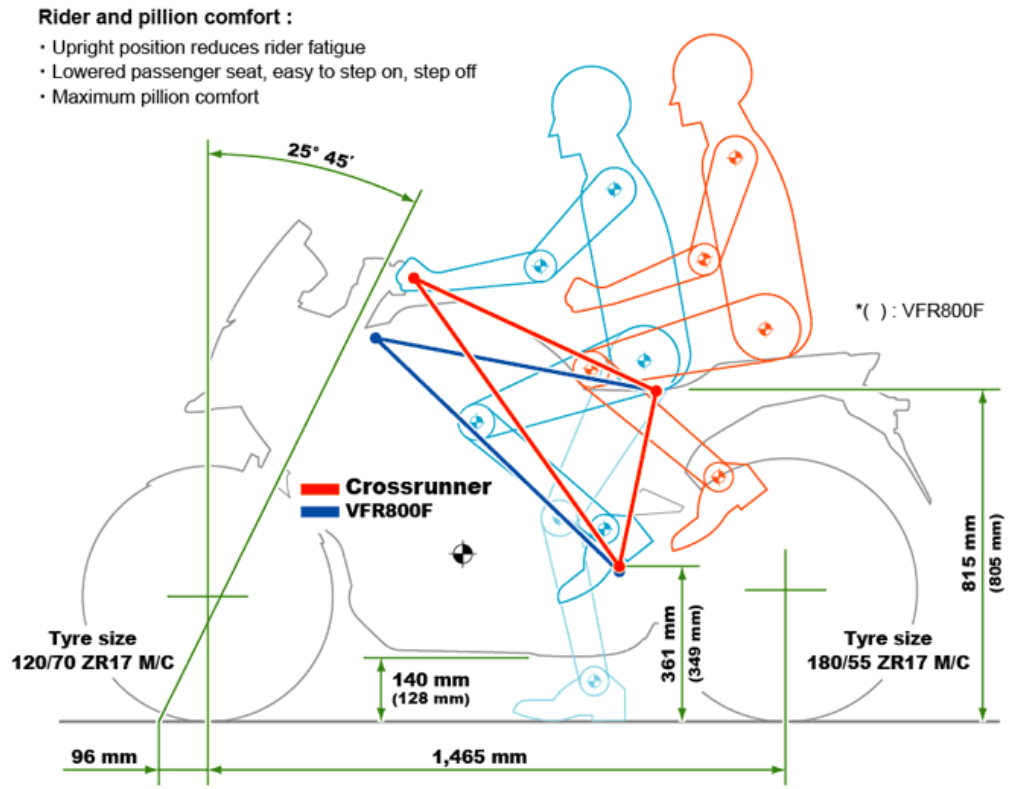
5.14 Frame geometrics comparison

The Frame geometry calculation is done in a separate document that can be found here.

Description of rake, offset, diameter, trail, and anti-squat:

- https://suspensionsecrets.co.uk/motorcycle-front-geometry/
- https://suspensionsecrets.co.uk/anti-squat-geometry/
- https://www.cycleworld.com/sport-rider/all-about-geometry/
- https://cycle-ergo.com/ for ergonomic seat position, not just big bikes!
- https://www.researchgate.net/publication/234080587_Motorcycle_dynamics_library_in_Modelica geometry paper with vectors and simulations from 2006
- https://evmc2.wordpress.com/2014/12/20/design-notes-center-of-gravity/
-

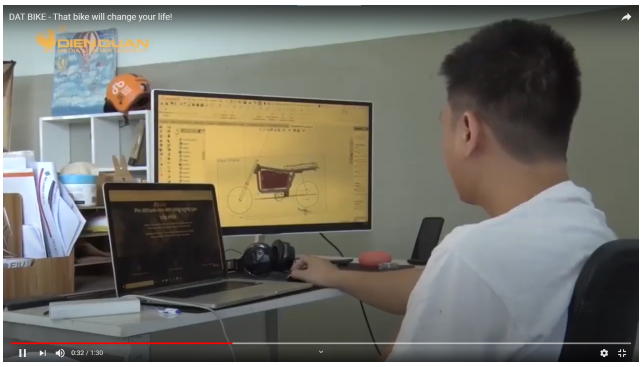
Dimension/ riding position comparison image

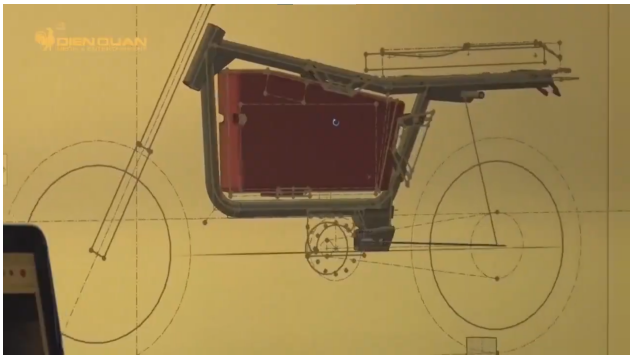


	Exciter	Winner	Airblade	SH125i	Pega-S	Weaver	Dream C100MP
length	1970	2019	1870	2090	2200	1840	1861
width	670	727	686	739	710	730	673
height	1080	1088	112	1129	1160	1000	1043
mass [kg]	115	124	113	133	160	85	94
wheelbase	1290	1278	1286	1353	1520	1270	1200
power [kW]	11.3	11.5	9.64	9.6	3.2	3	6.4
cm^3	150	149	149	124			97
front	70/90-17	90/80-17	90/80-14	100/80-16	100/80-16	70/90-17	60/100-17
rear	120/70-17	120/70-17	100/80-14	120/80-16	120/80-16	80/90-17	70/90-17
							Bike from 2000

Simulation: In Algodoo http://www.algodoo.com/download/ you can … do a lot!!

Who designed the Dat Bike? In this video from November 2020 we get a glimpse:

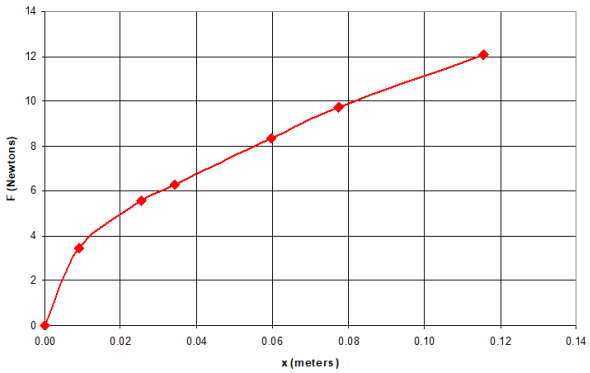




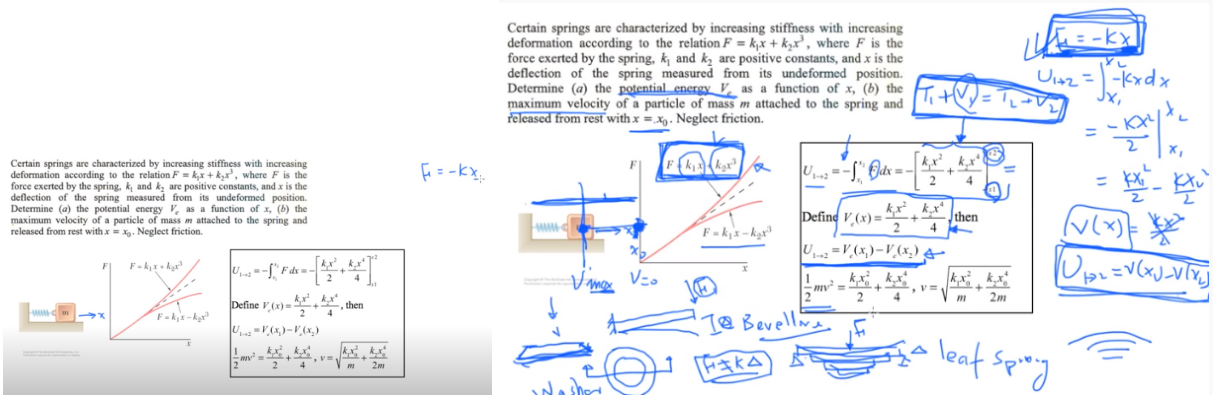
Is this a 3D model in Fusion 360, hovering over a simple 2D drawing without rake and trail?

Another observation: How much is the distance of the front wheel when fully compressed suspension considered in the dimensions of this design? Same for the rear wheel, the maximum travel seems limited which either limits the maximum load (here just 130kg) or requires stiffer suspension (higher spring constant) which lowers riding comfort.

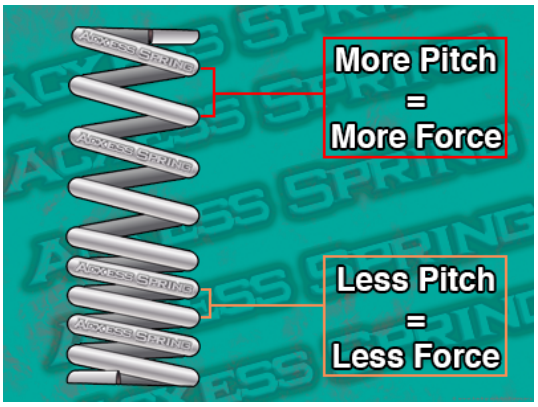
What about a suspension system with a nonlinear force diagram? Not rubber band as [investigated by sciencebuddies](), but … well



Look for example at [this video from Taiwan]() from 2011.



Why do we like it? To have little compression for the static load like the bike itself and the rider and more travel for the absorption of shocks. See at
https://www.acxesspring.com/non-linear-springs.html



Let's go into the math and see if some resonances could be removed. I found this lecture from the Ohio state university to get some details from Duffing's equation and some MATLAB simulations.

Cubic nonlinearity with or without quadratic nonlinearity

When we do Taylor series of an odd function about an equilibrium for with spring force = 0

Duffing's equation $m\ddot{x} + c\dot{x} + kx + \alpha x^3 = F_0 \cos \omega t$ (cubic)

When we do Taylor series of odd function about an equilibrium with spring force not = 0 (Recall HW1 for illustrative example)

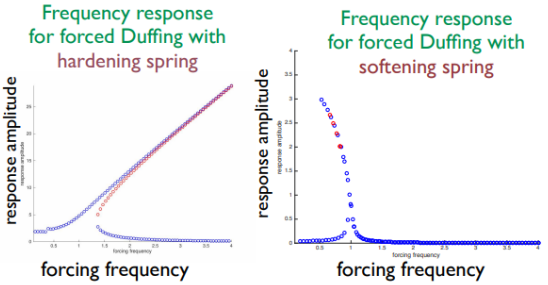
$$m\ddot{x} + c\dot{x} + kx + \alpha x^3 + \beta x^2 = F_0 \cos \omega t$$

cubic quadratic

(or) just Taylor series of a not-odd function

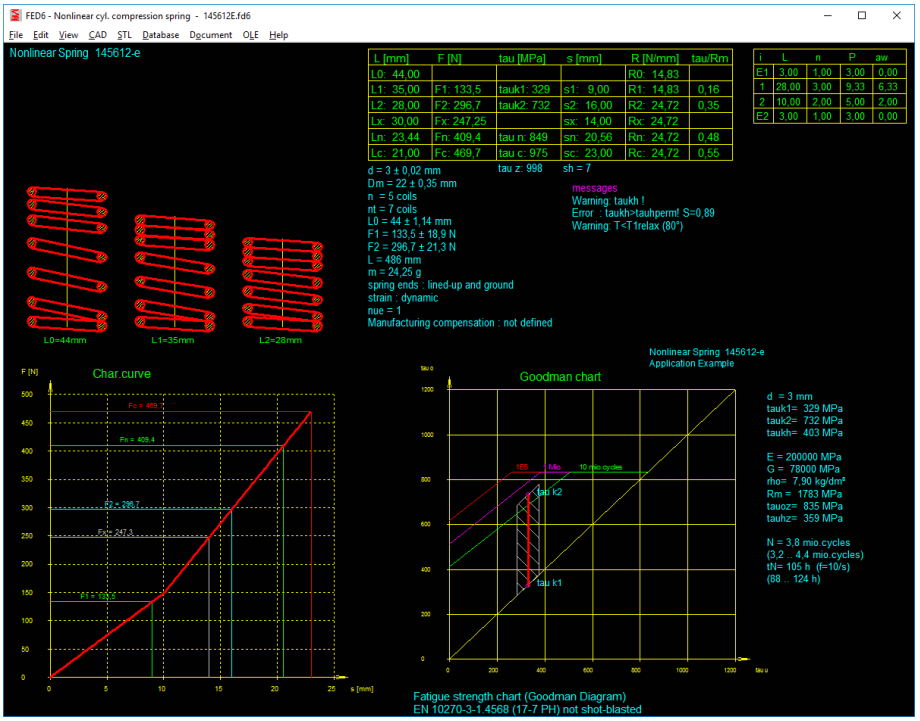
Amplitude response obtained by finding fixed points of Poincare maps (so we can find both stable and unstable motions)

see MATLAB program



blue = stable periodic response
red = unstable periodic response

You would like to simulate this? No problem, HEXAGON is here to help. Software: FED6



And for the frame itself …

5.15 Light: Halogen vs. LED

The regular head light of the weaver is a 30 W halogen bulb [definition needed]. It can be replaced by a LED light, available on the website for 200,000 VND. As for the published data this looks legit, but the size of the light bulb let's me doubt the given values. That's mainly from my own experience. Given values:

- Halogen 30W (496 lumens, Osram 800 lm (datasheet), 3300K, Bosch 405 lm, Osram 64261 750lm)
- LED DC985V, BA 20D, 6000K, 1080lm - it should be visibly twice as bright

My Nouvo has a Philips HS1 lamp with 35W/35W Halogen. I replaced several LED lamps because they stopped working after some time despite being actively cooled (fan in back). I tried a newer one without cooling and it does generate light, but only 10% and at the wrong spot. Would be great if Dat Bike solved the problem.

5.16 Suspension system

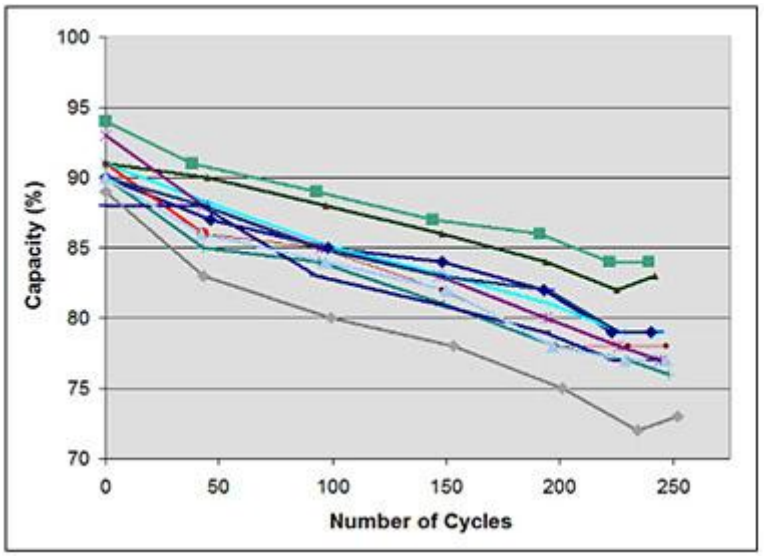
Measured values on a Honda Vario 150i. Front suspension 80mm, rear suspension 90mm. Average suspension with 80kg driver: 20mm. Spring constant therefore: F = 800N for g=10m/s^2 and s = 20mm. The spring constant for one spring there (directly to the rear axis with CVT) is therefore according to the formula F = Ds: D = F/s = 800/20 = 40 N/mm. And it is a progressive spring!

Maximum load when no suspension is left would be F = Ds = 40 * 90 = 3600 N = 360kg. Good for mom, dad, coworker, friend and small child. Plus whatever was shopped and has to be brought home.

5.17 How long will the battery last?

My own experience and the GPS data collection of recent years indicate an average traveling speed in HCMC of 35 km/h. Some parts might be faster, but the next traffic jam is just around the corner. Let's put this into perspective.

With this speed the Dat Bike can run 100km on one charge of the battery. For driving my bike 10,000 km each year I would have to charge it at least 100 times. The average lifespan of an NMC battery is maybe 500 cycles down to 70%. According to batteryuniversity.com this could be reached much earlier.



My Nouvo now has 87,000 kilometers, which would require at least 870 charging cycles. And it is 13 years old. How sustainable are electric bikes?

The Sony 18650 VTC6 batteries 3000 mAh 30A const now 59000 VND. A battery pack of 200 of these cells would cost 11,800,000 VND or 507.77 USD. The capacity would be 3.7*3*200 = 2220 Wh and result in a price of 507.77/2.22 = 229 USD/kWh. That is the projected price for a battery replacement every 5 years or 50,000 km. This might be good to take into account. Maximum power output of this pack would be 3.7V * 30A * 200 = 22.2kW = 30PS. This short term power equals some 400ccm motorcycles.

Update 2020/12/24 Trung is actually working on improving battery life of the INR18650MJ1.

5.18 How difficult is a BLDC driver?

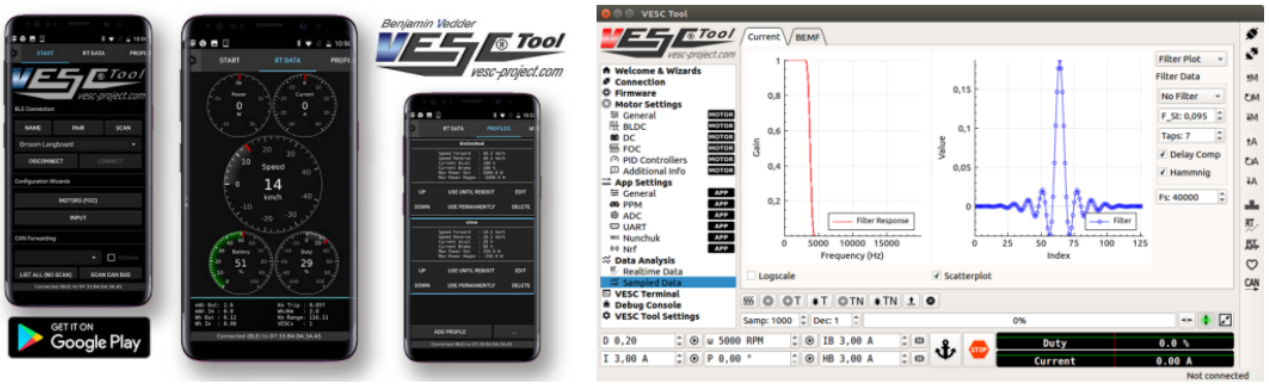
I read several times that Dat Bike is working on the BLDC driver to improve regenerative braking and other characteristics. On December 24th I was surprised that the supplier actually caused a problem in the delivered product. The controller could be programmed, but with changed MOSFETs it would faster overheat - and customers would complain.

Can you build one by yourself? Sure, GreatScott made a video series (part1, part2) in 2017 with 1.5 million and 500,000 views. In 2018 he investigated, if it makes sense to build a controller like the VESC by yourself (DIY) or if you should buy it (DIY or BUY VESC).

How much does a BLCD driver cost?

- VESC 75V 250A 420£ or 570$
- 48V 60V 72V 84V 3000W hub motor controller 24mos MAX80A aliexpress $49.70
- VESC4.2 60V 50A 50.26$
- FSESC75200 75V 200A Waterproof $298.50
- 60A Longboard Electrico FSESC 6.6 based upon VESC® 6 60V $131.72

And the software?



The VESC software tool can do so many things!

Need to try the several controllers and BLDC I got early 2020 eventually!

And I'm curious. The EIS (Eastern International University) has a lab to drive electric motors directly above the offices of Dat Bike, but there is no collaboration. Could a professor help? Could this be a part of a student project? Collaboration? There is quite some test equipment. And probably sensors, models, examples, and so on. Who knows …

Back to BLDC driver:

- Sine Wave Controller 3000W 60V-72V $72.02
- Could not find supplier and further information, like interface etc.

This rather new one calls himself "sine wave controller". Is this a fancy way to say FOC?

5.19 FOC Field Oriented Control of BLDC

The video from GreatScott from 2018 explains the advantage of the FOC mode of an ESC from theory (6 points in phase space time versus circle) and its effects on noise and torque in practice. Not completely new, TI has a presentation from 2012, referring to the initial design from a German engineer at Siemens F. Blaschke and TU Darmstadt K. Hasse in 1968. BTW: the TU Darmstadt is in collaboration with the VGU at the EIU! Wikipedia calls this https://en.wikipedia.org/wiki/Vector_control_(motor)

One thing I observed in October 2020 when driving first the Dat Bike was the noise when starting the bike, coming from the BLDC. What was the reason? Obviously the 60 degree driver.

And I thought to outsource the ESC for the BLDC would be a simple solution. Obviously not. If the driver needs 3000W to drive 60km/h constantly that is 1000W per phase, at 72V the current would be P=VI or I=P/V=1000/72 = 13.9A. Can we use just a IRFB4020PBF for 19000 VND?

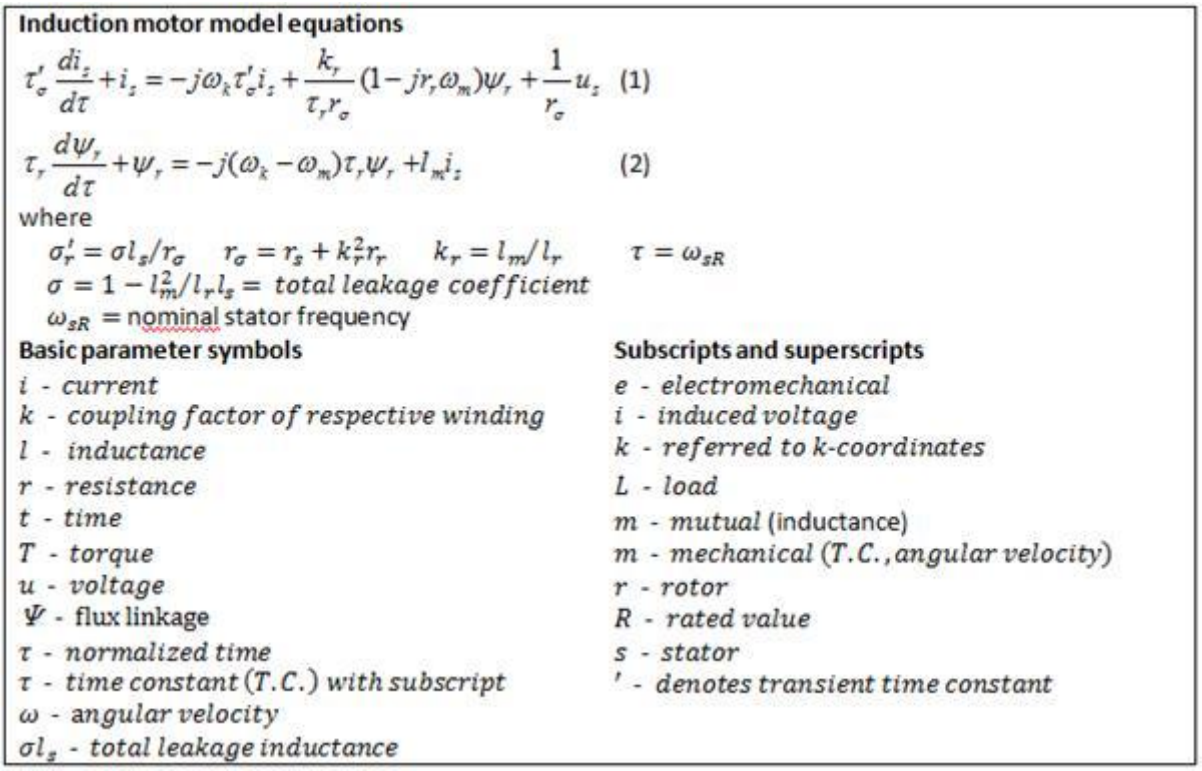
The MOSFET has 100 mOhm at 11A (max source drain voltage 200V, continuous drain 18A, max power 100W) so let's assume that's the same for the 14A case we have. $P=I^2R$ from R=V/I and P=VI or V=IR. In our case that's $P=I^2R=14^2 * 0.1 =$ **19.6 Watt**. The TO-220 could easily handle this with proper cooling (let's limit it to 80 °C) but inside the aluminum battery box of the weaver together with the two other regulators for the other phases you have a heat source of **60 Watt**. No wonder you get overheating problems. The right MOSFETs and a proper cooling solution is needed.

And since the current is quadratic, for the peak power of 5000W you have 23 Ampere per phase, but the heat produced by each MOSFET would be 53 Watt or **159 Watt combined!** That's toasty near the battery pack.

What other MOSFETs could we use?

Type	Max voltage	Max current	Max power	Max temp	resistance	Power @14A	Price
Link thegioiic	Vdss [V]	Id [A]	Tc [W]	TJ [°C]	mOhm	Watt	VND
IRF640NPBF	200	18	150	175	150	29.4	9,500
IRF540N	100	33	130	175	44	8.6	12,000
P75NF75	75	80	300	175	11	2.2	16,000
IRFP460	500	20	280		270	52.9	28,000
IRF3710L	100	57	200		23	4.5	38,000
FQA38N30	300	38.4	290		85	16.7	45,000

And the math behind the Vector Control is not that simple, you have to solve several differential equations. If you study physics that's part of the first semester, but for the average engineer not an everyday task. It would look like this:



Induction motor model equations

$$\tau'_\sigma \frac{di_s}{d\tau} + i_s = -j\omega_k \tau'_\sigma i_s + \frac{k_r}{\tau_r r_\sigma}(1 - jr_r\omega_m)\psi_r + \frac{1}{r_\sigma}u_s \quad (1)$$

$$\tau_r \frac{d\psi_r}{d\tau} + \psi_r = -j(\omega_k - \omega_m)\tau_r \psi_r + l_m i_s \quad (2)$$

where

$\sigma'_r = \sigma l_s / r_\sigma \quad r_\sigma = r_s + k_r^2 r_r \quad k_r = l_m / l_r \quad \tau = \omega_{sR}$

$\sigma = 1 - l_m^2 / l_r l_s =$ *total leakage coefficient*

ω_{sR} = nominal stator frequency

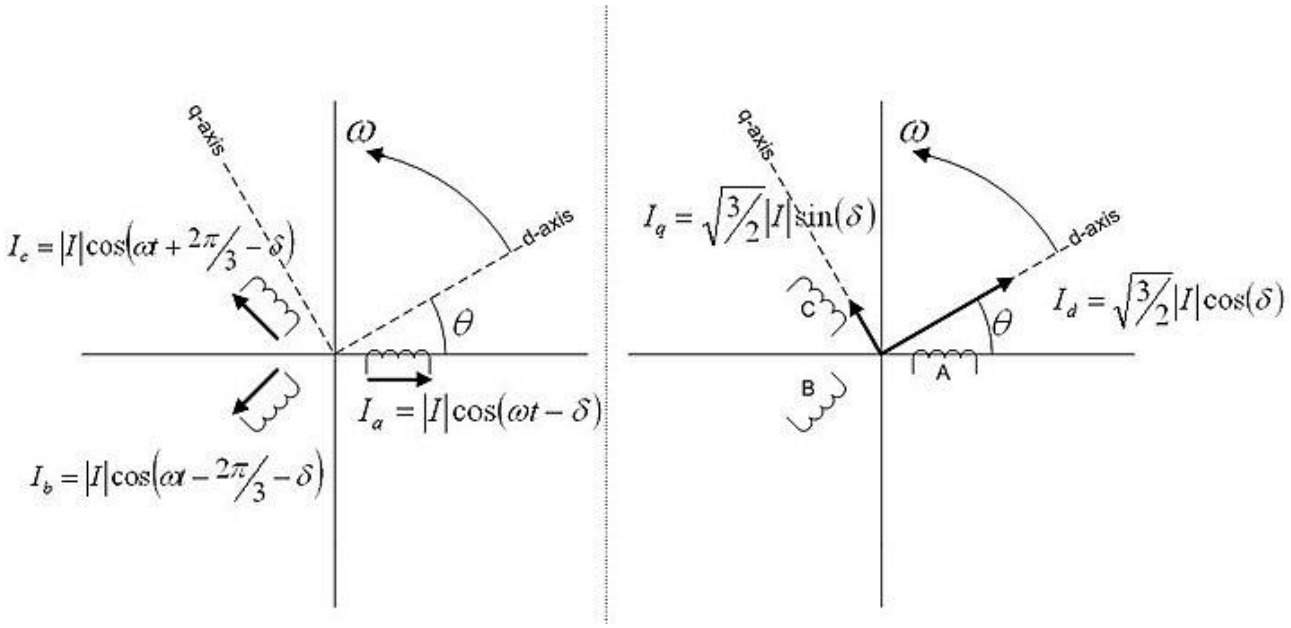
Basic parameter symbols

i - current
k - coupling factor of respective winding
l - inductance
r - resistance
t - time
T - torque
u - voltage
Ψ - flux linkage
τ - normalized time
τ - time constant (T.C.) with subscript
ω - angular velocity
σl_s - total leakage inductance

Subscripts and superscripts

e - electromechanical
i - induced voltage
k - referred to k-coordinates
L - load
m - mutual (inductance)
m - mechanical (T.C., angular velocity)
r - rotor
R - rated value
s - stator
' - denotes transient time constant

And then there is the Park Transformation from 1929.



With

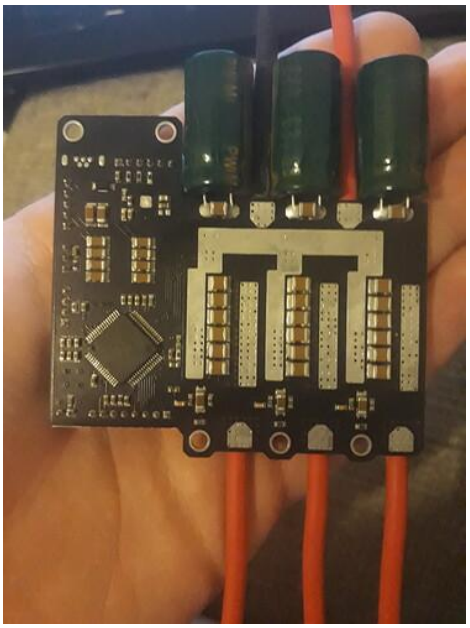
$$P = \frac{2}{3}\begin{bmatrix} \cos(\theta) & \cos(\theta - \frac{2\pi}{3}) & \cos(\theta + \frac{2\pi}{3}) \\ \sin(\theta) & \sin(\theta - \frac{2\pi}{3}) & \sin(\theta + \frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \qquad P^{-1} = \begin{bmatrix} \cos(\theta) & \sin(\theta) & 1 \\ \cos(\theta - \frac{2\pi}{3}) & \sin(\theta - \frac{2\pi}{3}) & 1 \\ \cos(\theta + \frac{2\pi}{3}) & \sin(\theta + \frac{2\pi}{3}) & 1 \end{bmatrix}$$

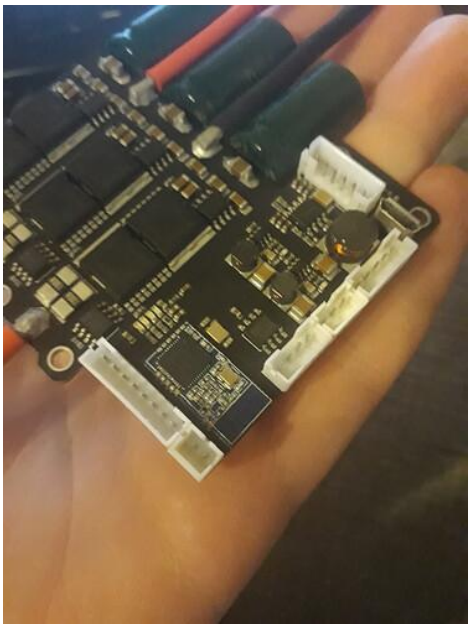
Matrix calculation and Linear Algebra - I love it!

5.19.1 VESC project by Benjamin Vedder and others

So this could be applied in an improved VESC like BESC with hall sensors for the current.

My investigation found that Janty SVK from Slovenia developed an upgraded High power VESC 6.4 variant and released the build files. 6x IPT007N06N mosfets and 3x UCC27211 mosfet drivers.





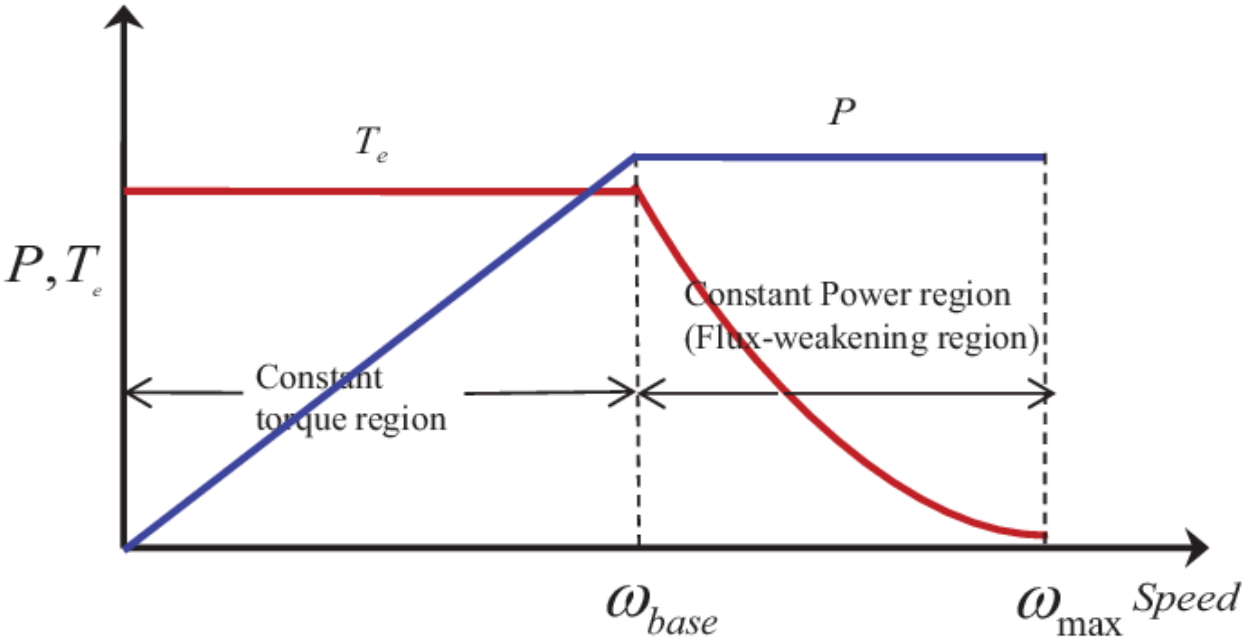
You can order one for 46$ by yourself, or PM him to get one for 70€ with bluetooth, CAN, ESC tested, XT60 input connector and so on. The shipping costs with slovenska posta 500g to vietnam is 6 Euro. Forum link https://forum.esk8.news/t/prototyping-high-power-vesc-6-4-variant/32036/51

Values for his IPT007N06N mosfet: only 0.66mOhm resistance! Bypass capacitors only 63 Volt, not suitable for Dat Bike. But what about modifications? He started in June 2020 and finished in December 2020. Updated the design in the meantime.

Can you go faster than the base speed of the BLDC? Yes, with Field Weakening!

5.19.2 Field Weakening

Some project development is documented in the 100kW AXIOM project from May 2019 at hackster.io. But you need special electronics, and have to consider the overvoltage (and overcurrent) to not fry your electronics.



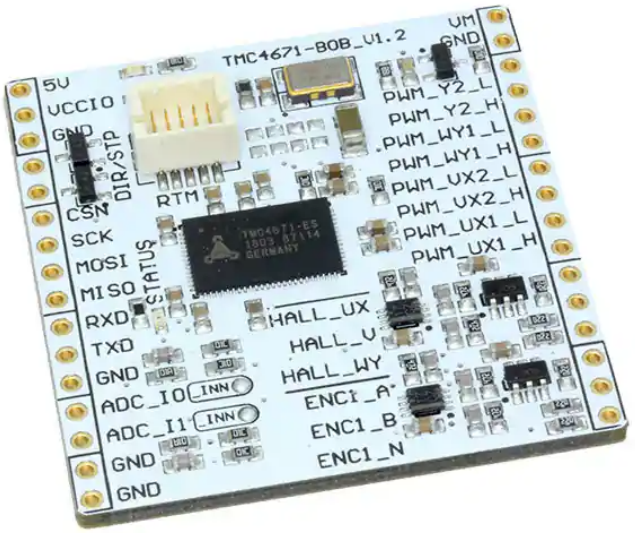
The list of scenarios is long. Maybe just a software error in the STM32F4 and an uncontrolled amount of current flowing to the battery, so a few things will happen:

- A large regen current will flow to the battery and the motor will act as a brake.
- If the powerstage can handle the current, great mechanical stress will happen with the possibility of losing control of the vehicle.
- The current will flow into the battery for as long as the motor is above base speed, this could be milliseconds or several seconds, as it's fueled by the inertia of the vehicle. Current could be well beyond 1kA, and the power dissipated by each body diode could reach several kW.
- If the powerstage can't take this amount of fault current, then the battery fuse or contactors should trip, and this unfolds another dangerous scenario: you are exchanging an uncontrolled current by an uncontrolled voltage. When the battery is disconnected it will no longer clamp the powerstage voltage and it will rise to whatever BEMF the motor is generating at that speed. Possibly destroying the inverter.
- Some applications allow fault management that shorts the 3 motor phases if the load has a small inertia, probably not the case of an EV.

Shortening the phases is not an option. What is the solution?

5.19.3 Professional solution by Trimatic

While it is an interesting project with VESC and rather hobby oriented, there are professional solutions created by engineers that implement the features in hardware with a robust design. One option is the TMC4671 controller from Trimatic. The data sheet explains a little of the theory as well and has 151 pages and is constantly updated!



A breakout evaluation board costs 49,00 Euro.

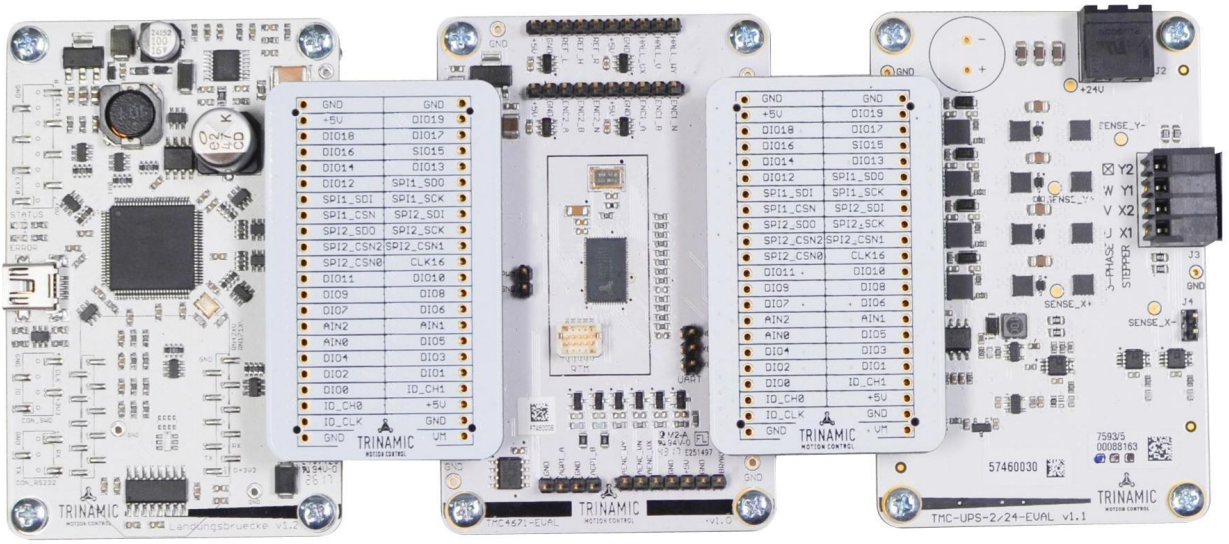
It seems there is a lot to learn about driving a BLDC properly. Trimatic makes the silent drivers for 3D printers like Prusa MK3. Guess they know what they are doing. Now bought by Maxim. Operating in Hamburg.

Further literature:

- Feldorientierte Regelung der permanenterregten Synchronmaschine ohne Lagegeber für den gesamten Drehzahlbereich bis zum Stillstand (dissertation 131 pages, german, 2007)
- Roboteq website information
- Maccon information 13 pages pdf

As for the current and voltage sensing of the Trimatic 4671 it has a 16 bit resolution. But there might be a need for a sense amplifier (AD8418)

The complete evaluation kit of CPU, Driver and MOSFETs is more 354 dollar, or 302 dollar at Farnell.



No worries, the chip itself is 15,57 Euro at Farnell.

The reasons for a dedicated chip are explained at 3.3 Why FOC as pure Hardware Solution on page 9.

6 Speculations about a possible future

The first four subheadings (6.1 to 6.4) are from December 2019.

6.1 Fine Tuning - v2.1 January 2021

Some of the old design flaws are addressed and finally fixed. The electronics and software part got an update as well:

- Finally a circuit breaker is added for a basic measure of safety
- Finally the foot rest for driver and ride pillion is relocated and now connected to the sprung mass, further forward and lowered (driver) respectively higher
- ICU upgraded with storage and CAN interface in the upgraded battery box
- Internal I2C bus is extended with ZS-042 to store (24C32N) synchronized (DS3231M) cycle data
- Location data and bike health characteristics is connected to the cloud over Viettel 2G
- Sensor upgrade. The ICU controls now 5 more values, getting closer to Gogoro with 80 sensors
- The regenerative braking is not updated to provide adjustable PWM battery recharge because the evaluation showed the negligible effect on the efficiency
- The updated seat his 80% higher and offers 130% more comfort

The updated seat is a new accessory or paid upgrade for the 200 existing DatBike users.

6.2 Power upgrade - v2.2 February 2022

With an electronics upgrade the battery can deliver the maximum power of 7.2kW from the existing 200 18650 cells. The regular power of the new motor is 5000W. The upgrade is therefore:

- New motor, more powerful: 5000W sustained, 7200W peak
- New battery controller to deliver this power
- Battery controller and BLDC electronics relocated to different housing than the battery for safety reasons and heat management
- 60% higher acceleration
- Companion app for iOS and Android is released, connects to bike using BLE
- Software update for BLE functionality, GATT is easy. Now displays the 10 sensor values on the smartphone and allows bike customization like acceleration curve or individual regenerative braking percentage. More information like cycle count of the battery, average travel distance per charge in last month/year and estimated finishing charging time can be shown

6.3 Redesign 2021 - v3.0 April 2021

A paper from May 2019 [mdpi2019] discussed many improvements that finally lead to the new design v3.0. Several calculations (comfort, frame design) of this paper are reflected in the document you just read. What's new? A complete new design, battery, motor, frame - almost everything is new! Key parameters:

- Trellis frame, split frame, single shock absorber for swingarm
- 3000 Wh battery, removable, lower center of mass
- 5000 W motor (8000 W peak) - design anticipates larger power options for later upgrade in key definition parameters
- Relocated set position, more central, pillion is 200mm higher than driver seat

- Sophisticated cable design to make almost all wires invisible, because they are inside the frame or hidden under some new introduced plastic shields
- Sporty design resembles wedge shape (Honda Winner) instead of classic horizontal practical design from 1980 (Honda Win)
- Seven defined contact points (fork with 14 degree rake, 280mm swingarm connector x2 and bike back part (seat, fender) x4)

The new defined seven contact points allow to offer a wider variety of customization and models, where just the back part has to be exchanged or the swingarm be updated to accompany a stronger motor.

Actually I'm pretty curious how the new design will look like. See further at Dat Bike 3.0.

6.4 Power upgrade - v3.1 October 2021

The homologation process took a little longer, but the concept of James Biggar in New Brunswick, Ontario, Canada suited as inspiration. In 2-4 weeks he built a custom bike with 12kW motor (24kW peak), described the process in a 30 minutes video and published his design files for his electric streetfigher https://www.resystech.com/electric-streetfighter.html.

DatBike has now 3 power options, two battery sizes and 3 options for driver seat and pillion. The color options are extended to 6 colors: bluegreen sky, bluegreen grass, orange, firered and black.

Well, this was all written well before COVID-19 and the electric boom that followed. And bikes like the Metacycle.

Revision History

1987/09/14 Solder an electric circuit to power an electromagnet, here a radio that fits into a cassette tape box
1993/05/20 Design, manufacture, assemble and paint aluminum housing structure, here for Atari ST 520
2000/03/16 Riding with a Honda XR 250 across Sansibar, 18 kW
2000/05/07 Got my first motorbike, a Yamaha XT600 43F (1984) with 43L tank and 33 kW
2007/06/10 Develop a Java program for scientific data analysis, using a software versioning system
2007/07/18 First CAD design for foreigners, here sample heater for MBE (Molecular Beam Epitaxy) to be used with ZrS and ZrSe on a Boralectric 220 Watt electric heater in UHV (Ultra High Vacuum) for our Egyptian PhD researcher, designed in Autodesk Inventor 6 and Inventor 2008. The design melted the aluminum (660 °C), new heat shield from copper (1085 °C) lasts hopefully longer
2012/07/13 Successful coaching of a team to win a design competition (Formel (Z)ukunft)
2014/07/29 Joris father picked him up after the treehouse project with a Volkswagen e-Up! Electric car with 60kW engine and 18.7kWh battery.
2015/12/30 First App released at the Google Play Store
2018/02/17 First ride with an electric bike in Bagan/Myanmar. Probably 800W motor. Initial **a** is great
2018/02/20 Electric bike idea starts for Nguyễn Bá Cảnh Sơn in California, he quits his job after 2 days and starts to learn, watch youtube videos and get an electric bike from Walmart to figure out how it works and how to improve [khpt2019]
2018/07/06 Conversation with german engineer in Arenal Volcano National Park, battery values documented back then are: Bolt 60 kWh 440kg 160kW NEDC 500km (2.4 kW); Zoe 22kWh 275kg 65kW 210km (2.1 kW) or large 41kWh 300kG for 400km (2.05kW) with rental for battery of 69€/month or buy 8900€ - 217€/kWh. Zoe @100km/h 10kW, NEDC average speed of 18.35km/h and Qicycle battery 36V/5.8Ah. He was driving a unu Classic with 1.5 kW and a possible option to upgrade to 3 kW in Aachen (many hills)
2019/04/25 History video of development of v1.0 starting in California
2019/09/26 Featured in Shark Tank Vietnam, 1.1 million views, many company details
2019/10/25 Price goal for dat bike was 60 million VND as seen here, video has constructive feedback
2019/10/29 Featured by Ninja Teachers in a video,
2020/02/27 First batch delivery of version v2.0 in HCM
2020/10/23 Khoa at AISVN, first ride on Dat Bike with 3 kW (5kW??)
2020/10/29 First battery capacity calculation in a jupyter notebook
2020/11/21 Shop in Saigon opens at 49B Tú Xương, Phường 7, Quận 3, TP HCM
2020/11/25 Visit of Eastern International University, where one part of the assembly is located
2020/11/26 Visit of new store at 49B Tú Xương, Phường 7, Quận 3, TP HCM
2020/11/27 Started this document as v0.1 with some basic information and battery calculations
2020/11/28 Extended Improvements listing and competition
2020/11/30 Max power of battery calculation, added website improvement
2020/12/02 Link to bikes list, unsprung mass calculation
2020/12/04 The circuit breaker is missing! Even the weak Capa+ has one. Unsprung mass jupyter
2020/12/12 Geometric design and physical simulation ...
2020/12/19 Test Drive with the Pega-S in HCMC
2020/12/24 Second visit in Binh Duong. No R&D or new model planned, but improving quality. For example the supplier for the BLDC driver changed the MOSFETs that now overheat much easier. Now Dat Bike develops its own driver (see https://vesc-project.com/) with

circuits from JLCPCB. Actually, that is R&D. And a Bluetooth update would count as such too. Not sure if PCB is v4.0 or own KiCAD 6.0
2021/01/06 Updated some information on the FOC hardware driver from Trimatic in 5.19.3
2021/03/03 Updated Fisker interview with Verge and Sondors Metacycle and Evida.vn, third visit HQ
2021/04/14 Update funding $2.6 million by JungleVentures
2021/11/26 The new Weaver 200 is released. Finally an iOS app. A good central stand. Larger battery, more power. The footrest for the pillion is mounted to frame, not swingarm. FINALLY!
2021/12/13 Found the book "Build your own electric Motorcycle" from Carl Vogel (released July 2009) in the teacher's lounge at SSIS. Someone is interested in this topic!
2021/12/16 Met Dat Vo at SSIS. He worked for dat.bike in 2019. Now he designs with students.

Blog entry #1: https://dat.bike/blogs/dat-bike-blog/cong-suat-dong-co-dien (2020-09-16):

First link: Vietnamese registration authority:
http://203.162.20.156/vaq/Xecogioi_sxlr/FoundDetail_tso_mto.asp?sid=813852
And the claimed 5000W are written there as well. Here is a screenshot (image of bike is missing)

Maximum 5 kW is written, but the engine type (Động cơ: Nhãn hiệu : **QSMOTOR 72V3000W**)

Technical data about bikes - vietnamese database from Vietnamese Register http://vr.org.vn

Nouvo 3, 4, 5, 6, NXV155, dat.bike and Pega-S in this document

2020/12/03 Should I write an extended essay? I now have 4443 words!
2020/12/06 More like 7870 words. And 26 pages.
2020/12/09 Google states 10053 and 32 pages
2020/12/21 13807 words on 47 pages
2020/12/29 16491 words on 56 pages
2021/03/03 17396 words on 59 pages
2021/12/16 17961 words on 61 pages

Almost the same geometry:

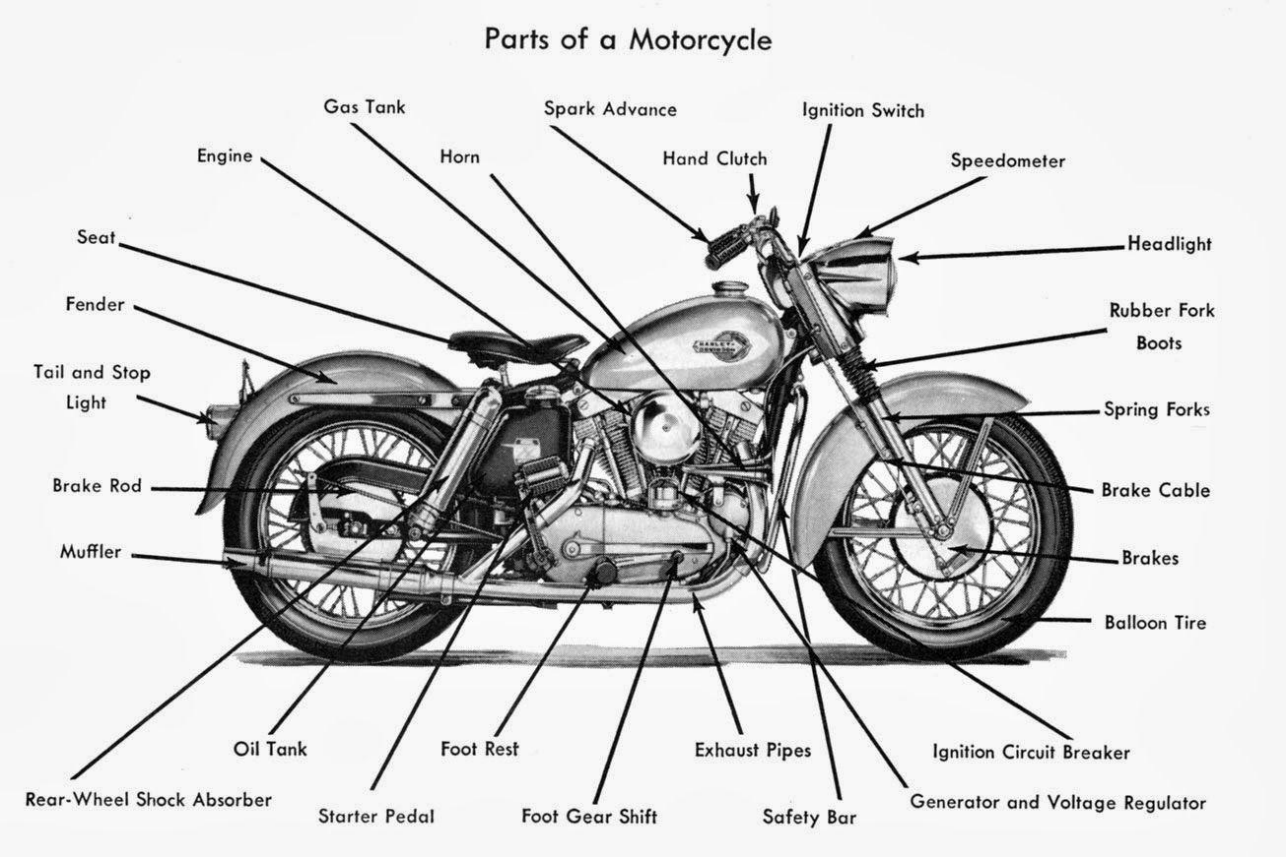
Appendix

A1 Measurements on the Dat Bike Weaver

I took some measurements with the included AR app “measurekit” in the iPhone and got several values very accurate, for example the wheelbase.
[pictures]
link to vr.org.vn:
Weaver (2020)
Weaver 200 (2021)

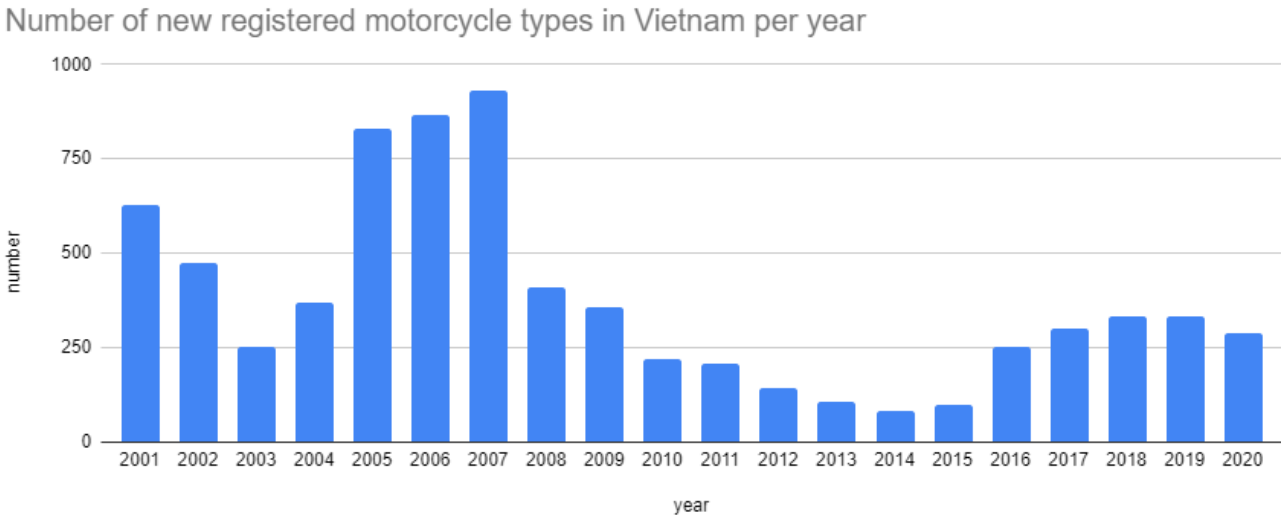
A2 Characteristics of the Honda Dream

Some characteristics of the Dat Bike Weaver resemble the classic style of the Honda Dream, for example the 17 inch spoke tyres and the rather flat seat. The wheels are 2.25 - 17 / 2.5 - 17 in the old imperial denomination. This would translate to 55/90-17 / 65/90-17.

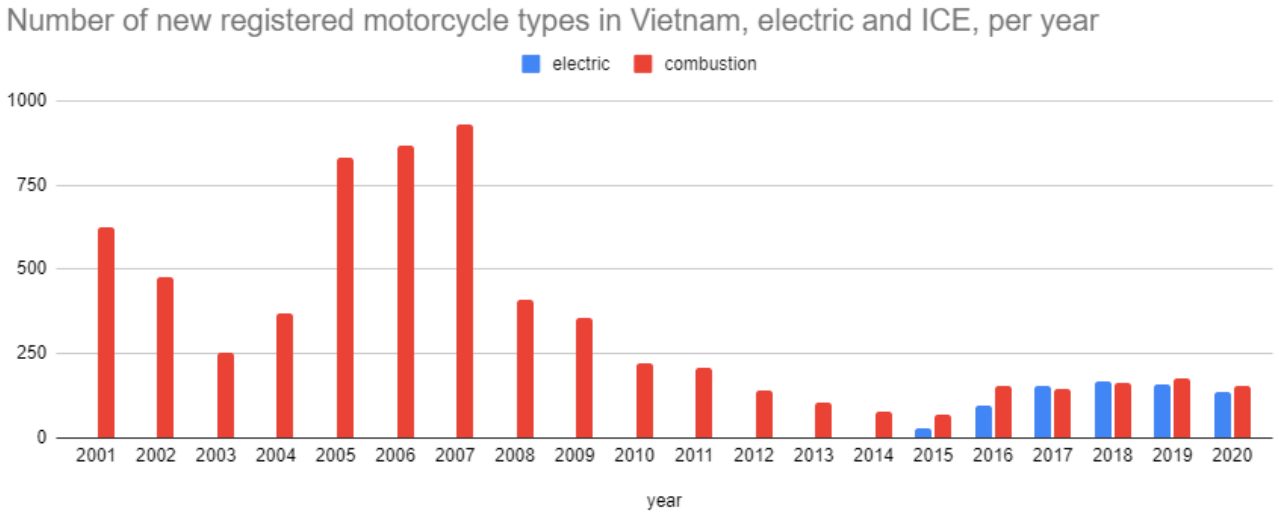


A3 The Vietnamese Register vr.org.vn

This database lists 7517 different registrations for motorcycle types in Vietnam. Here is a Google Sheet version. Even my old Linda can be found there! And it's hard to believe that in 2007 almost 1000 different types of motorcycles were registered. How different can they be?



And some 747 models (10%) of all these registrations are electric bikes. Don't be fooled, though. It does not mean variety by any means. While checking for correct power values and determination in this list I found that more than 50% (403) of all these models are different rebranded X-Men with 800W motors. Let's include them, the first electric bike was registered 2013:



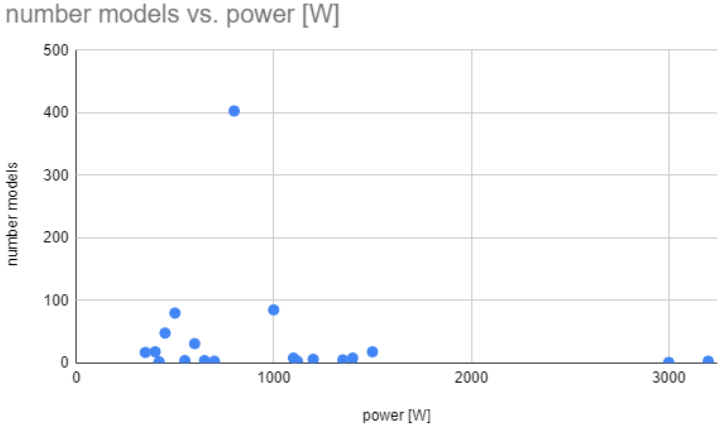
But let's start anyway. The clear peak is at 800W as of now.

power [W]	400	450	500	550	600	650	700	800	1000	1100	1200	1350	1400	1500	3000	3200
# models	25	42	70	3	30	2	3	350	86	8	4	5	8	12	1	3

Some other findings:

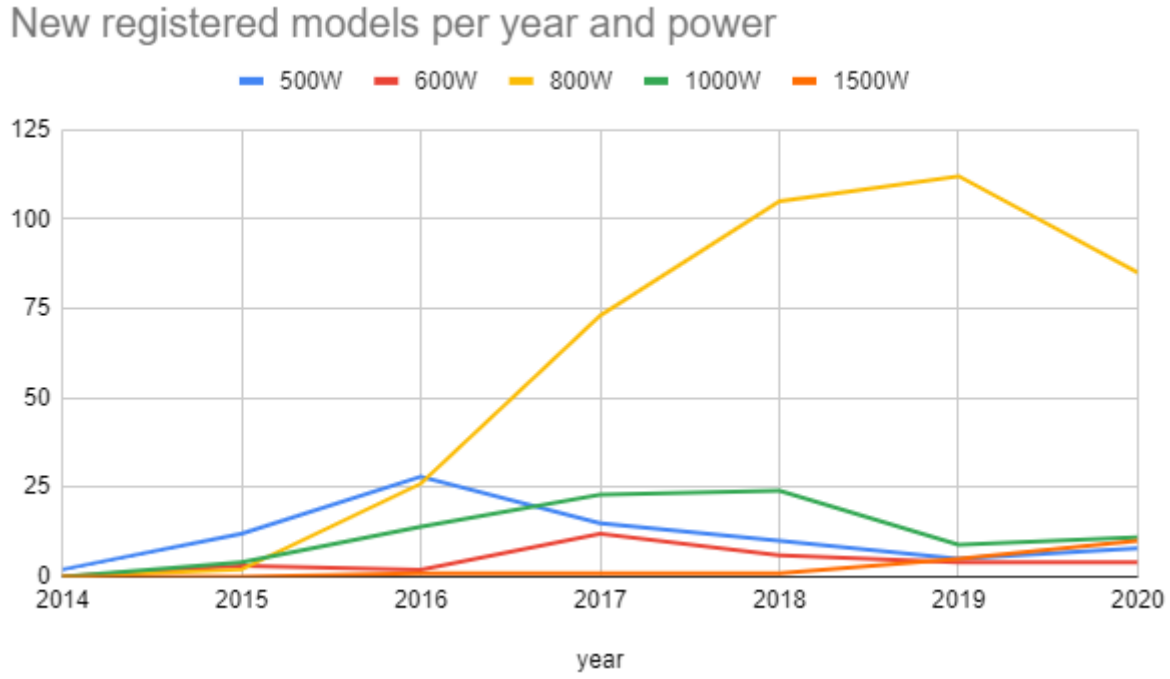
- 500 models just for Honda
- 2000 are registered for Vietnam and China (Trung Quốc và Việt Nam)

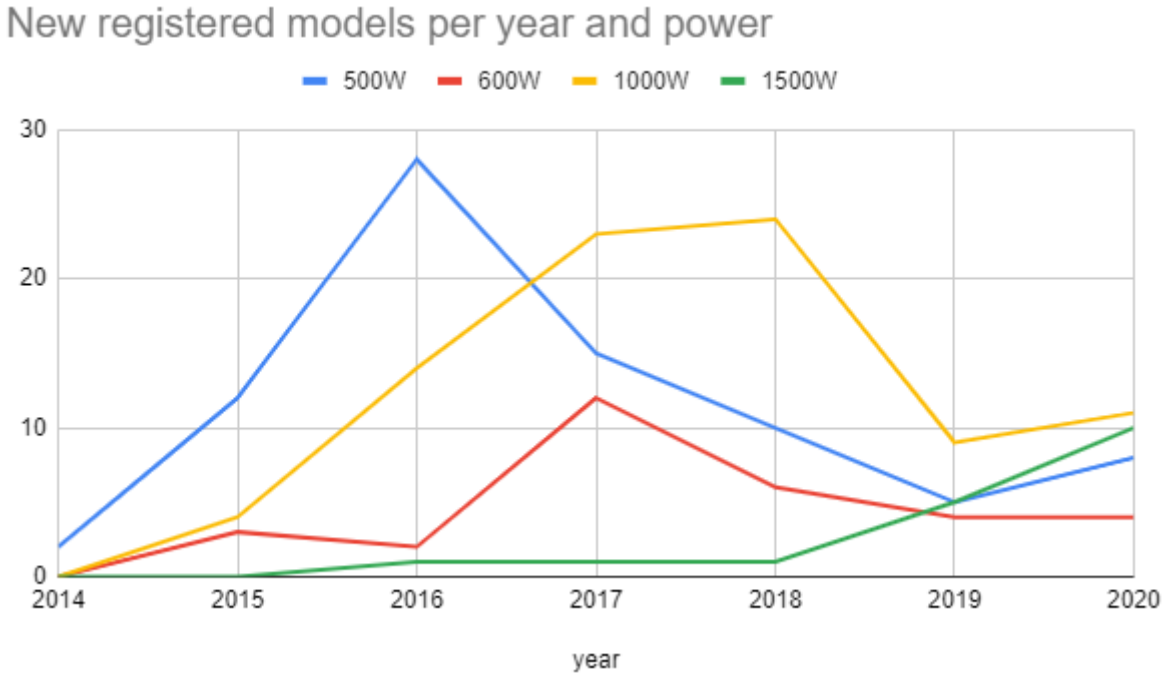
A clear trend is visible in the number of new registered electric bikes and the shift to higher output power over the last years. The first electric bike was only registered in 2013!



If a motorbike is registered, the database contains information about other countries, where this bike is registered. You can see the target market of the manufacturer for different models. The early Honda Airblades for example were registered in Thailand and Vietnam (2007-2013). Some SH150 are solely registered for Italy.

But for electric bikes there is only the combination of China and Vietnam. For all 746 models - with one exception: Dat Bike. But this was already pointed out by vietcetera [vietcetera2020] in May 2020.





There are some questions regarding registration. According to vnexpress it is planned to introduce driving licences for electric bikes up to 4kW and scooters with 50cc until 2025. As of 2020 no driving license is required. Yet for Pega-S you need a licence plate for 4 million VND. What about smaller bikes?

Law regulation in Vietnam:

- Electric bikes up to 250W need no registration
- Electric motorcycles with more than 200 W need a registration, cost: 4,000,000 VND
- Motorcycles need a registration, depending on the selling price:
    - 5% of the selling price as Tax.
    - Licence plate depending on selling price
        - Up to 15 million VND: 1,000,000 VND
        - Up to 40 million VND: 2,000,000 VND
        - More than 40 million VND: 4,000,000 VND

And what about a driver licence? Link to official document: no need for electric and below 50cc

A4 New registered motorcycles statistics

There is a nice written article about the history of motorcycles in vietnam by citypassguide. And Honda only started to produce motorbikes in Vietnam in 1998 and had many problems! With all registration and requirements it was twice as expensive to produce a motorcycle in Vietnam compared to Thailand.

Yearly production: 5.5 million (Honda, Yamaha, Suzuki, Piaggio)

Motorbikes sold
2011: 3.3 million
2012
2013:
2014:
2015: 2.82 million
2016: 3.12 million

Motorbikes registered
1990: 500,000 (source)
2004: 14 million (source)
2007: 18 million (Vietnam enters World Trade Organisation, lifts ban of >175cc bikes, source)
2009: 24 million (source)
2013: 37 million (source)
2017: 45 million registered bikes (source)

Electric bikes sold
2020: VinFast 120,000 (more than 10,000 per month)

Electric share: If 3 million new motorbikes were sold and VinFast sold 150,000 that's **5%**.

Pega: have to look for numbers, but their new model Pega-S was scheduled for 38,900,000 VND and is now for the first batch of 30000 reduced to 30,900,000 until March 2021. That's almost a year! And only slightly more expensive than the NewTech (21,700,000 VND)

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