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PUV - Personal Utility Vehicle

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Abstract—This paper describes the design and fabrication of Personal Utility Vehicle (PUV). The idea of PUV was acquired from researching about the extended applications of Segway. The Segway is based on the principle of inverted pendulum that will keep an angle of Zero degrees with vertical at all times. The Segway uses gyroscopic sensors to detect the motion of rider, so that user can accelerate, brake or steer the vehicle. One of the predominant limitation is that Segway is not an all-terrain vehicle and also it runs on batteries that cannot be replenished easily. The Segway also does not have a brake system onboard. By introducing a caterpillar wheel as well as an engine to the system, required traction can be achieved. The concept presented here introduces an all-terrain vehicle which is better in performance as compared to that of a Segway. Also by adding attachments the PUV can be made suitable for farming, transportation etc.

I. INTRODUCTION

Personal transporters are the two wheeled, self-balancing and electric motor driven devices such as the Segway. The Segway PT is the first two-wheeled, self-balancing, electric personal transportation device invented in 2001. Segway is also put into category— ‘‘Electric Personal Assistive Mobility Device EPAMD. The literature on the Segway and its interaction with the other road users is limited to empirical data, dynamical characteristics of the Segway and subjective assessments based on the surveys and questionnaires which were aimed to guide the policy-makers and traffic regulation bodies.

The approach distance and velocities of the Segway riders to the various obstacles and pedestrians at the different velocity profiles are analyzed in [1,2]. The experiments were implemented under the controlled conditions by recruiting ten novices and ten experienced operators. A similar study [3] reports the stopping distance for the different driving maneuvers including emergency braking and response time of the riders when braking. The collected Segway riding data were also compared to the running characteristics of bicycles. In the study [4], the observed reactions of the vehicle drivers and passing distance to the different types of personal mobility devices including the Segway are given in detail. The experiments in the study were performed on road crossings while the drivers were turning left. The reports of some pilot projects which report the safety requirements of Segway on the shared footpaths, opinion from the various stakeholders and institutions and the subjective assessments of the recruited riders are presented in [5,6]

The travel information of the Segway is collected with a simple software application installed on the widespread mobile devices attached to the Segway and the methods, algorithms and applications to collect travel information from the PTs by these devices are presented [7]. The algorithms make use of the sensors of a mobile device such as a cell phone or a tablet PC, an Android tablet. The application developed for these devices align the sensor measurements to the motion coordinate system first. The aligned sensor readings then become readily available for analyzing the lateral and longitudinal dynamics of the mobility robots, as well as for investigation of the interaction between the other travelers.

The results on the modeling and control of a two-wheeled prototype named B2, like the Segway, is principally a self-balancing machine whose wheels share a common axis and is presented in [8].

The energy-based stabilization and speed control of a wheeled inverted pendulum, which is an underactuated, unstable mechanical system subject to nonholonomic constraints is dealt in [9,11]. It uses the method of Controlled Lagrangians for the stabilization of an equilibrium characterized by the length of the driven path, the orientation, and the pitch angle. The methodological approach for combining technology assessment of the major subsystems of a PEV with a technical model of vehicle performance in order to estimate the cost and mass of a vehicle for a given set of functional requirements is presented in[10]

The *wheeled inverted pendulum* (WIP) – and its commercial version, the Segway [2015, Jan] – has gained interest for human assistance and transportation in the past several years due to its high maneuverability and simple construction .On the basis of DEM theory, a numerical sand model for traction tests with the help of PFC3D 4.0 software (ITACSA, 2008) is established and the tractive performance, including tractive parameters and lug effects numerical tests are carried out under different steering conditions and its presented in [12].

The influence of torque distribution on tractive efficiency of wheeled off-road vehicles is investigated in [13]. Tires allow the vehicle to convert the energy delivered by the engine into useful work (motion) and therefore they influence vehicle dynamics and mobility. In order to realistically evaluate the tractive efficiency of a full-size vehicle it is necessary to properly model the dynamics of the tires and the vehicle body. For this reason, a thorough off-road tire model is explained and a 14 degrees of freedom vehicle model is implemented.

The issue of wheeled vehicles vs. tracked vehicles for off-road operations has been a subject of debate for a long period of time. Recent interest in the development of vehicles for the rapid deployment of armed forces has given a new impetus to this debate. While a number of experimental studies in comparing the performances of specific wheeled vehicles with those of tracked vehicles under selected operating environments have been performed, it appears that relatively little fundamental analysis on this subject has been published in the open literature, including the Journal of Terramechanics. The tractive performance of wheeled and tracked vehicles from the standpoint of the mechanics of vehicle–terrain interaction evaluated in[14]. Two computer simulation models, one for wheeled vehicles, known as NWVPM, and the other for tracked vehicles, known as NTVPM, are described. As an example of the applications of these two computer simulation models, the mobility of an 8 · 8 wheeled vehicle, similar to a light armored vehicle (LAV), is compared with that of a tracked vehicle, similar to an armored personnel carrier (APC).

Very few off-road vehicles are used exclusively under off-road conditions. Good off-road mobility dictates large high aspect ratio tyres with aggressive tread, low inflation pressures, soft suspension for good comfort as well as other vehicle parameters including large ground clearance and the related high center of mass. This results in less-than-satisfactory vehicle handling and high rollover propensity on hard terrains at higher speeds. In order to simulate vehicle handling and roll over propensities, on non-deformable terrain, tyre characteristics in the form of side-force versus slip-angle curves, as well as suitable tyre models are required. For large off-road tyres these characteristics are not readily available. A study is made to measure side-force versus slip-angle characteristics for a Michelin 16.00R20 XZL tyre – typically used on off-road trucks in [15] The data is used to parameterize Fiala, UA (University of Arizona), Pacejka89 and FTire models. Simulation results are compared to both steady state and dynamic handling test results to determine the accuracy of these models. 2015 ISTVS.

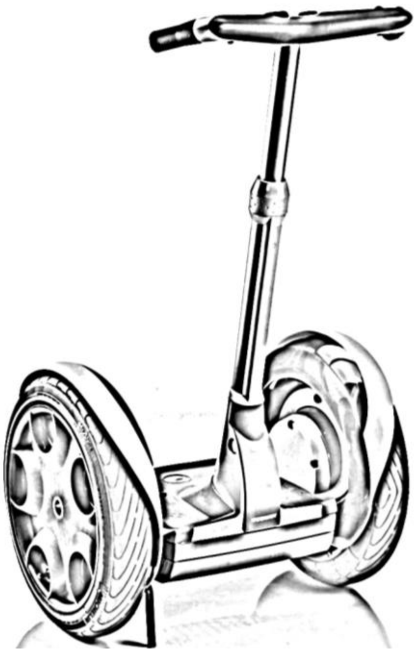

Figure 1: Segway

In this paper, a concept for the design and fabrication of a personal transport is presented named as the Personal Utility Vehicle (PUV). It is an all-terrain, engine powered vehicle. The engine and the cater pillar wheels are the factors that differentiate PUV from Segway since it proposes higher speed and power as well as stability. In PUV Balancing is achieved by the wheel itself so that use of complex sensors can be avoided. Turning is achieved by cutting the power to one wheel as done in conventional vehicles which uses caterpillar tracks. PUV can be used a transportation vehicle as well as a carrier vehicle (Using attachments at the rear end). PUV uses an existing petrol engine that of 'Honda Activa' and intern uses the continuously variable transmission. In conclusion after these changes the flexibility of the machine will increase many folds.

II. COMPONENTS

A. Continuous track

Continuous track also called tank tread or caterpillar track is a system of vehicle propulsion in which a continuous band of treads or tracks plates is driven by two or more wheels. This band is typically made of modular steel plates in the case of military vehicles and heavy equipment, or synthetic rubber reinforced with steel wires in case of lighter agricultural or construction vehicles. The large surface area of tracks distributes the weight of the vehicle better than steel or rubber tyres on an equivalent vehicle, enabling a continuous tracked vehicle to traverse soft ground with less likelihood of becoming stuck due to sinking. The prominent treads of the metal plates are both hard-wearing and damage resistant, especially in comparison to rubber tyres. The aggressive treads of the tracks provide good traction in soft surfaces but can damage paved surfaces, so some metal tracks can have rubber pads installed for use on paved surfaces.

Modern tracks are built from modular chain links which together compose a closed chain. The links are joined by a hinge, which allows the track to be flexible and wrap around a set of wheels to make an endless loop. The chain links are often broad, and can be made of manganese alloy steel for high strength, hardness, and abrasion resistance.

Track construction and assembly is dictated by the application. Military vehicles use a track shoe that is integral to the structure of the chain in order to reduce track weight. Reduced weight allows the vehicle to move faster and decreases overall vehicle weight to ease transportation. Since track weight is completely unsprung, reducing it improves suspension performance at speeds where the track's momentum is significant. In contrast, agricultural and construction vehicles opt for a track with shoes that attach to the chain with bolts and do not form part of the chain's structure. This allows track shoes to break without compromising the ability of the vehicle to move and decrease productivity but increases the overall weight of the track and vehicle. Extra weight is an advantage when optimizing for traction and power over speed and mobility

The vehicle's weight is transferred to the bottom length of track by a number of road wheels, or sets of wheels called bogies. Road wheels are typically mounted on some form of suspension to cushion the ride over rough ground. Suspension design in military vehicles is a major area of development; the very early designs were often completely unsprung. Later-developed road wheel suspension offered only a few inches of travel using springs, whereas modern hydro-pneumatic systems allow several feet of travel and include shock absorbers. Torsion-bar suspension has become the most common type of military vehicle suspension. Construction vehicles have smaller road wheels that are designed primarily to prevent track derailment and they are normally contained in a single bogie that includes the idler-wheel and sometimes the sprocket.

Transfer of power to the track is accomplished by a drive wheel, or drive sprocket, driven by the motor and engaging with holes in the track links or with pegs on them to drive the track. In military vehicles, the drive wheel is typically mounted well above the contact area on the ground, allowing it to be fixed in position. In agricultural crawlers, it is normally incorporated as part of the bogie. Placing suspension on the sprocket is possible, but is mechanically more complicated. A non-powered wheel, an idler, is placed at the opposite end of the track, primarily to tension the track, since loose track could be easily thrown (slipped) off the wheels. To prevent throwing, the inner surface of the track links usually has vertical guide horns engaging grooves, or gaps between the doubled road and idler/sprocket wheels. In military vehicles with a rear sprocket, the idler wheel is placed higher than the road wheels to allow it to climb over obstacles. Some track arrangements use return rollers to keep the top of the track running straight between the drive sprocket and idler. Others, called slack track, allow the track to droop and run along the tops of large road wheels. This was a feature of the Christie suspension, leading to occasional misidentification of other slack track-equipped vehicles.

Figure 2: Continuous Tracks

The continuous band of treads driven by a series of wheels is used when the wheels cannot be used. In this area, can be added a variety of scenarios, including the move on uneven terrain or when it’s needed high traction. In general, continuous tracks are used for:

- **Power Efficiency** - Compared with wheels, continuous tracks have high performance and optimized traction system, which is a plus in power delivery efficiency;
- **Traction** - The traction is high even on slippery surfaces like snow or wet concrete.
- **Moving on Rough Terrain** – Using continuous tracks, a PUV can operate on rough terrain while the wheels can get stuck. Also, the continuous band of treads can ascend and descend stairs, surmount obstacles, or cross ditches.
- **Aesthetics** – The tracks look more aggressive than wheels.
- **Ground impact** – A PUV that moves on rubber tracks has a lower PSI (Pounds per Inch) on the ground. That means a less impact on the ground, especially considering the weight of the PUV and when someone on the heavier side is riding it.
- **Weight growth potential** – A PUV with continuous tracks has a weight spread over the entire surface of the track. This is one of the reasons that a PUV with rubber tracks support a heavy person and additional loads.

Advantages

Tracked vehicles have better mobility over rough terrain than those with wheels. They smooth out the bumps, glide over small obstacles and are capable of crossing trenches or breaks in the terrain. Riding in a fast-tracked vehicle feels like riding in a boat over heavy swells. Tracks cannot be punctured or torn. Tracks are much less likely to get stuck in soft ground, mud, or snow since they distribute the weight of the vehicle over a larger contact area, decreasing its ground pressure. In addition, the larger contact area, coupled with the cleats, or grousers, on the track shoes, allows vastly superior traction that results in a much better ability to push or pull large loads where wheeled vehicles would dig in. Bulldozers, which are most often tracked, use this attribute to rescue other vehicles, (such as wheel loaders) which have become stuck in, or sunk into, the ground. Tracks can also give higher maneuverability, as tracked vehicles can turn in place without forward or backward movement by driving the tracks in opposite directions. In addition, should a track be broken, assuming the correct tools are available, it can be repaired without the need for special facilities; something which is crucial in a combat situation

Disadvantages

The disadvantages of tracks are lower top speed, much greater mechanical complexity, shorter life and the damage that their all-steel versions cause to the surface on which they pass. They are assumed to severely damage hard terrain such as asphalt pavement, but actually have significantly lower ground pressures than equivalent or lighter wheeled vehicles. However, they often cause damage to less firm terrain such as lawns, gravel roads, and farm fields, as the sharp edges of the track easily rout the turf. Accordingly, vehicle laws and local ordinances often require rubberized tracks or track pads. A compromise between all-steel and all-rubber tracks exists: attaching rubber pads to individual track links ensures that continuous track vehicles can travel more smoothly, quickly, and quietly on paved surfaces. While these pads slightly reduce a vehicle's cross-country traction, in theory they prevent damage to any pavement.

Additionally, the loss of a single segment in a track immobilizes the entire vehicle, which can be a disadvantage in situations where high reliability is important. Tracks can also ride off their guide wheels, idlers or sprockets, which can cause them to jam or to come completely off the guide system (this is called a 'thrown' track). Jammed tracks may become so tight that the track may need to be broken before a repair is possible, which requires either explosives or special tools. Multi-wheeled vehicles, for example, 8 X 8 military vehicles, may often continue driving even after the loss of one or more non-sequential wheels, depending on the base wheel pattern and drive train.

Many manufacturers provide rubber tracks instead of steel, especially for agricultural applications. Rather than a track made of linked steel plates, a reinforced rubber belt with chevron treads is used. In comparison to steel tracks, rubber tracks are lighter, make less noise, create less maximal ground pressure and do not damage paved roads. The disadvantage is that they are not as solid as steel tracks. Previous belt-like systems, such as those used for half-tracks in World War II, were not as strong, and during military actions were easily damaged. The first rubber track was invented and constructed by Adolphe Kégresse and patented in 1913; rubber tracks are often called Kégresse tracks.

Prolonged use places enormous strain on the drive transmission and the mechanics of the tracks, which must be overhauled or replaced regularly. It is common to see tracked vehicles such as bulldozers or tanks transported long distances by a wheeled carrier such as a tank transporter or train, though technological advances have made this practice less common among tracked military vehicles than it once was.

B. Engine

PUV Uses an existing engine, that of Honda Activa. The engine specifications are given below

Engine description	102 cc,4 Stroke
Cooling	Air cooling
Maximum power	7 bhp @ 7000 rpm
Maximum torque	7.8 Nm @ 5500rpm
Number of cylinders	1
Transmission used	Automatic, CVT
Air filter type	Viscous paper filter

Table 1: Engine Specifications

Advantages of IC Engine Over Electric Motor in the PUV

- **Portability** - Many larger electric motors are not easily portable, and even if a motor is small enough to be portable, it has to be taken into consideration that the battery wouldn’t be able to provide the sufficient power for the PUV.,
- **Demand Charges** - Using high-horsepower motors in PUV is required where they are run infrequently (Low Load Factor) can result in costly electrical demand charges which results in higher consumption of power from the batteries and which may lead to the depletion of the battery earlier than presumed.
- **Remote Locations** - Expensive line extensions are sometimes needed for installation in remote locales where existing electrical power is not available so as to just charge the PUV especially as the fossil fuels are generally readily available.
- **Cost factor** - An electric motor, especially when coupled with a battery pack, costs a lot more than a traditional gas engine.
- **Frequency of Recharge/ Refuel** - The frequent recharging of the electric motor can also be bothersome. As opposed to IC engines, electric motors don’t pack enough charge to travel long distance. If a bigger motor is considered, cost as well as weight is a huge issue.

- **Time Taken for Recharge/Refuel** - Electric motor needs to be charged more often as opposed to petrol engines. Time taken for charging is also considered. For example, if we consider an electric car, time taken to charge an electric car can take as little as 30 minutes or up to 12 hours. The time it takes to charge depends on the size of the battery and the speed of the charging point. A typical electric car (Nissan LEAF 30kWh) takes 4 hours to charge from empty with a 7kW home charging point. Whereas although fuels are on the higher priced side, petrol stations are much more common and can be filled up to full capacity in a matter of minutes.

C. Transmission

The Segway is driven by The two-stage transmission, built by Segway and Axicon Technologies, has a compact 24:1 gear ratio. It uses a helical gear assembly that significantly reduces noise. The Segway team configured the two meshes in the gear box (the points where gears connect) to make sound exactly two octaves apart. This means the sounds are in harmony, so the gear box make a more musical noise. The gears are also designed to have non-integer gear ratios, meaning the gear teeth mesh at different points from revolution to revolution. This minimizes wear and tear to extend the life of the gear box.

PUV uses continuously variable transmission (CVT), A continuously variable transmission (CVT) (also known as a single-speed transmission, step less transmission, pulley transmission, or, in case of motorcycles, a twist-and-go) is an automatic transmission that can change seamlessly through a continuous range of effective gear ratios. This contrasts with other mechanical transmissions that offer a fixed number of gear ratios. The flexibility of a CVT allows the input shaft to maintain a constant angular velocity.

A belt-driven design offers approximately 88% efficiency which, while lower than that of a manual transmission, can be offset by lower production cost and by enabling the engine to run at its most efficient speed for a range of output speeds. When power is more important than economy, the ratio of the CVT can be changed to allow the engine to turn at the RPM at which it produces greatest power. This is typically higher than the RPM that achieves peak efficiency. In low-mass low-torque applications (such as motor scooters) a belt-driven CVT also offers ease of use and mechanical simplicity.

Instead of gears, the system relies on a rubber or metal belt running over pulleys that can vary their effective diameters. To keep the belt at its optimum tension, one pulley will increase its effective diameter, while the other decreases its effective diameter by exactly the same amount. This action is exactly analogous to the effect produced when gears of different diameters are engaged.

"Gear" Selection

Since one pulley is driven by the engine and the other is connected to the drive shaft, an infinite number of ratios can be produced. This enables it to always run at the most efficient speed, regardless of the load placed on it. Microprocessor-controlled sensors quantify load variations and by adjusting both pulleys, the optimum operating speed for the engine can be maintained without any input from the driver.

Figure 3: Continuously Variable Transmission

Advantages

CVT offers instant, step less acceleration throughout the engine's optimum operating range. It provides a comfortable ride by eliminating "shift shock". It also provides better fuel efficiency. Faster response to changing driving conditions such as variations in throttle and engine speed is offered. Eliminates energy losses associated with torque converters.

Disadvantages

CVT is unsuitable for use in extreme off-road environments because of limited torque-handling ability. Also, cannot provide engine braking.

D. Braking system

A disc brake is a type of brake that uses calipers to squeeze pairs of pads against a disc in order to create friction that retards the rotation of a shaft, such as a vehicle axle, either to reduce its rotational speed or to hold it stationary. The energy of motion is converted into waste heat which must be dispersed. Hydraulic disc brakes are the most commonly used form of brake for motor vehicles but the principles of a disc brake are applicable to almost any rotating shaft.

Compared to drum brakes, disc brakes offer better stopping performance because the disc is more readily cooled. As a consequence, discs are less prone to the brake fade caused when brake components overheat. Disc brakes also recover more quickly from immersion (wet brakes are less effective than dry ones).

Most drum brake designs have at least one leading shoe, which gives a servo-effect. By contrast, a disc brake has no self-servo effect and its braking force is always proportional to the pressure placed on the brake pad by the braking system via any brake servo, braking pedal, or lever. This tends to give the driver better "feel" and helps to avoid impending lockup. Drums are also prone to "bell mouthing" and trap worn lining material within the assembly, both causes of various braking problems.

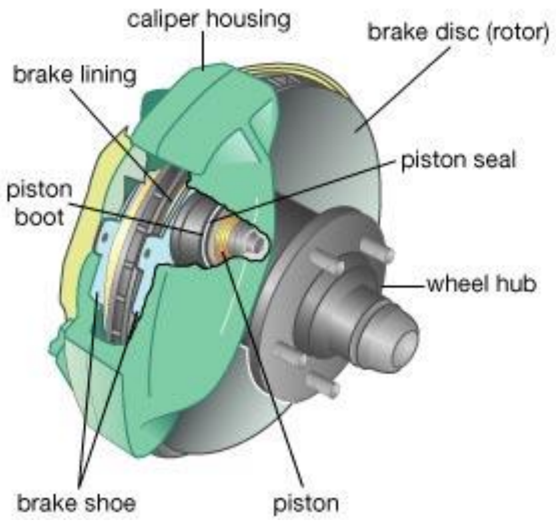

Figure 4: Disc Brake

The brake disc (or rotor in American English) is usually made of cast iron, but may in some cases be made of composites such as reinforced carbon–carbon or ceramic matrix composites. This is connected to the wheel and/or the axle. To retard the wheel, friction material in the form of brake pads, mounted on the brake caliper, is forced mechanically, hydraulically, pneumatically, or electromagnetically against both sides of the disc. Friction causes the disc and attached wheel to slow or stop.

The braking system of PUV consist of Disc brakes, a disc brake is a type of brake that uses calipers to squeeze pairs of pads against a disc in order to create friction that retards the rotation of a shaft, such as a vehicle axle, either to reduce its rotational speed or to hold it stationary. The energy of motion is converted into waste heat which must be dispersed. Hydraulic disc brakes are the most commonly used form of brake for motor vehicles but the principles of a disc brake are applicable to almost any rotating shaft. Compared to drum brakes, disc brakes offer better stopping performance because the disc is more readily cooled. FAs a consequence, discs are less prone to the brake fade caused when brake components overheat. Disc brakes also recover more quickly from immersion (wet brakes are less effective than dry ones).

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Whereas the Segway doesn't have a braking system. To stop, the rider stands upright without leaning forward or backward, and the vehicle maintains its position.

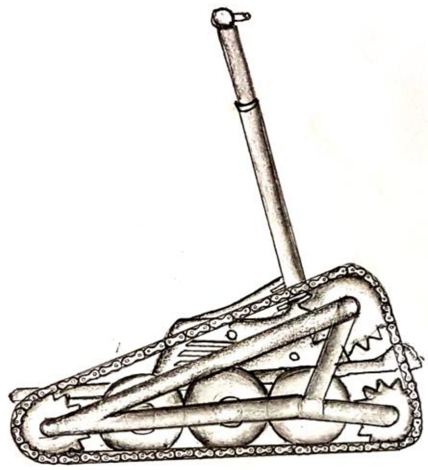

Figure 5: Side View of PUV

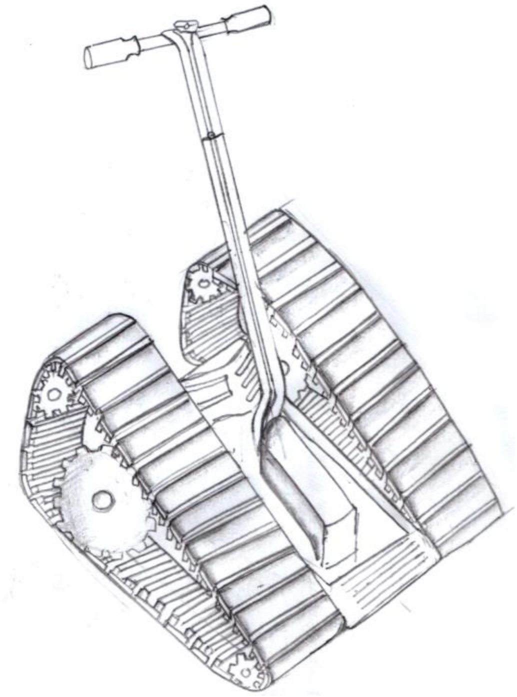

Figure 6: PUV

III. CONCLUSION

This paper proposes an efficient method of off road transport of a person using the PUV. It is an all-terrain vehicle as continuous tracks replace wheels. Also, it will not get stuck in soft mud as weight distribution is more uniform. Puncturing or tearing of tyres is not a problem. Different attachments can be attached as per requirement. Varied torque output according to requirement can be obtained.

IV. ACKNOWLEDGEMENT

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