Semi-automated Limited Mobility System for Immobilized Automobiles

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Abstract

This research focuses on enhancing the traditional single wheel jack and building a semi-automatic short-distance mobility solution for immobilized cars. The primary objective is to enable swift relocation of vehicles in emergency situations, eliminating the need to start the engine and, in the case of hybrid drive-train or electric cars, avoid the necessity of towing. The proposed innovation allows for easier car positioning and movement. This holds significant potential value not only for individual users but also to businesses, particularly those engaged in vehicle maintenance and recovery services, who will be able to use the improved convenience to enhance their efficiency in attending to immobilized vehicles or maneuver cars in highly space constrained places such as small-sized workshops. The technical foundation of this research is to understand the various car jack technologies in existence, bring in other related mechanical engineering and power conversion systems such as hydraulics and wheeled platforms, and integrate them into the concept product. The non-technical aspects considered focus on general utility, affordable costs of manufacture, and ownership and portability. Car jacks currently utilize various technologies, such as simple machines' mechanical advantage, hydraulics, and pneumatics. This paper explores the potential of employing pneumatics, hydraulics and screw/scissor-jack mechanisms to create portable, motorized jacks equipped with wheels that can be easily attached to any car's jacking points. The proposed end product will use a motorized scissor lift mechanism powered using the car's battery and will be mobile via omnidirectional wheels mounted on the bottom surface. There will be one jack per corner of the vehicle. To achieve this goal, advanced tools and methodologies, including Computer-Aided Design (CAD) in conjunction with a rigorous process of prototyping and experimentation will be employed. Through this comprehensive approach, the study presents a viable solution that enhances vehicle movement accessibility and efficiency during critical scenarios.

Introduction

This research project is driven by a personal experience of witnessing a hybrid car get stranded in a typical two-lane suburban road that held up traffic for upwards of 30 minutes until the tow truck came around, and took another 20 minutes until the traffic started to clear up. This situation would have been completely avoidable had there been a quick, portable solution to move the immobilized car sideways by about 5 meters onto the shoulder. While this accident was on a smaller road, accidents on larger roads have proven to cause significant delays to traffic; studies show that a single crash can cause 30-60 minute delays due to blockages, with the numbers growing exponentially during peak hour traffic (Retallack et al. 2019). This delay is largely due to the amount of time it takes authorities to clear the road of the damaged car; a task that would take mere minutes with the use of this paper's proposed product. The ultimate objective is to develop a more efficient and user-friendly car jack, specifically designed to facilitate the easy relocation of vehicles. Emergency situations can be one use, but the product can also be used by professionals in the automobile field such as mechanics to move cars easier in their shops. This can also be extended to hobbyist mechanics who need a simple and portable way to move their cars around in order to work on it. The backbone of this is to first understand existing car jack technologies, limitations and a thorough research on how to integrate the jack with a wheeled platform(s) and the construction of an integrated solution that aims to provide a multiplier effect over the existing piecemeal solutions. Traditional jacks often fail to meet critical requirements, particularly in situations demanding swift and hassle-free vehicle movement. Advanced pneumatic and motorized jacks are either not portable or are too expensive for a typical car user to carry in the boot. This project focuses on leveraging existing technologies to create a solution that enhances user convenience and operational efficiency.

During roadside breakdowns or emergency scenarios, the ability to swiftly relocate a vehicle without the reliance on engine ignition becomes not just a matter of convenience but a potential lifesaver, since there are multiple instances of stationary cars getting hit by traffic in unlit or dimly lit roads. The envisioned jack is conceived as a reliable, affordable, portable and accessible tool, providing crucial assistance to individuals facing unexpected automotive challenges.

The existing limitations of conventional car jacks underscore the necessity for innovation. Many currently available jacks lack the capacity to lift all four wheels simultaneously or lack features enabling lateral movement. These constraints impede the seamless relocation of vehicles, particularly in urgent situations. By addressing these drawbacks, the proposed jack aims to fill a crucial gap in the market, offering a solution that not only lifts vehicles effectively but also enables easy and precise movement when required. By overcoming these limitations, the envisioned jack seeks to provide a practical and impactful solution to the challenges faced by both individual drivers and professionals in the automotive industry.

Existing Car Jacks

Traditional car jacks are essential tools included with most vehicles, primarily designed for lifting a car to change a tire. The most common types of car jacks are scissor jacks, motorized scissor jacks, pneumatic jacks, and hydraulic jacks. Scissor jacks, commonly found in vehicle trunks, use a screw mechanism that, when twisted, expands the jack to lift the car. Motorized scissor jacks automate this process using an attached motor, offering a hands-free lifting experience. Pneumatic jacks operate with pressurized air to inflate airbags or activate pistons, lifting the vehicle quickly but requiring an external air supply. Hydraulic jacks utilize hydraulic fluid to amplify the mechanical force applied by the user, making them efficient but often bulky.

These jacks, despite their utility, share several limitations. Firstly, they are designed to lift only one corner of a vehicle at a time and do not facilitate moving a vehicle once lifted. Secondly, their portability varies significantly; while scissor jacks are compact, pneumatic jacks require cumbersome additional equipment like air tanks. Lastly, speed and ease of operation are not uniformly optimized across these jacks, with some being slow or requiring significant manual effort.

The proposed car jack design addresses the shortcomings of traditional jacks by incorporating omnidirectional wheels that allow a vehicle to be moved in any direction while lifted. This feature is particularly advantageous in emergency situations, such as minor accidents or breakdowns, where quick removal of the vehicle from traffic lanes is critical. Additionally, the design is compact and portable, with each jack compressing into a four-inch thick plate that can fit in any car trunk. This portability is complemented by its ease of use, as the jack system is powered by the car's battery via the cigarette port, requiring minimal setup and lifting the vehicle within 35 seconds.

In the car jack market, my design is positioned competitively at around \$1000, aligning with the higher-end motorized jacks while offering enhanced functionality. This price point reflects the advanced features such as motorized lifting, portability, and the ability to move the car omnidirectionally, while still being more cost effective compared to its pneumatic counterparts (which stand at around \$3500). The proposed design provides a significant improvement over existing jacks by meeting the critical criteria of enabling vehicle mobility while lifted, being highly portable, and operating quickly. Consequently, this innovative car jack presents a valuable solution for both emergency responders and automotive professionals, combining efficiency, portability, and enhanced functionality, thereby filling a critical gap in the current market.

Proposed Solution

Proposed solution is to build a set of four connected car jacks [see Figure 7], that can all be powered by the car battery outlet in the passenger cabin and can safely and efficiently be tucked in the boot of the car when not being used. Jacks will be scissor-lift type, that allows for easy attachment to the four jacking points, enabling simultaneous lift. Scissor lift mechanisms are also known to be very hardy, and can prove reliable for many years on end. Unlike traditional car jacks, this not only lifts vehicles effectively but also facilitates short-distance movement while the car is on the jack. Since the jack is not much more complicated than existing designs, the product can be very affordable and can compete with existing designs for motorized jacks. The jacks are powered by the car's battery, simplifying and enhancing the device's practicality. The device is operated by a remote control. Portability remains a key aspect of the design, ensuring convenient storage in the trunk for on-the-go accessibility.

Motorized operation is a standout feature of the proposed device. Leveraging the car's battery power, each scissor jack unit is motorized, significantly reducing the physical exertion required from the user. Additionally, a remote controller enhances emergency convenience, ensuring quick and hassle-free operation in critical situations. The motorized scissor jack design, coupled with the controlled operation of each unit, provides a versatile and efficient solution for various scenarios.

Power and speed-of-lift considerations:

One of the most important aspects is the power input that is available, and how best to utilize this and strike an engineering compromise between the ease of use, speed of the lift action, and the complexity of the set-up.

1. Each of the four jacks should be able to lift at most a third of the weight of a typical sedan, taken as 3500 pounds (~1,600 kg). Anything more in terms of capacity will make the set of jacks very heavy and unwieldy.
2. All four wheels have to be lifted up at the same time to prevent uneven weight distribution on any one corner, which implies that the available power output should be equally and simultaneously given to the four jacks

3. Peak power available is 120 W which after taking into account the losses, tolerances etc., can be considered as 110W, which implies each jack has 27.5W of available power, and a current rating of 2.2A.
4. Power * time = Work = weight * distance. Assuming the lift-up should be for 8 inches (= 8*0.0254m), to lift 400kg (times acceleration due to gravity), we get about 35 seconds as the time required to lift-up all four jacks, running full tilt.
5. However there will be friction, inertia and start-up losses as well as limitations of the torque that can be effectively delivered in a small form-factor design, that may increase this by 3x to 4x, so we can take 2 minutes as max lift time.
6. This time duration is not very long, and will fit into the overall target time of 3-5 minutes to move the car out of the road.
7. To mount a DC motor of 22.5W will also not make the jack very heavy (each motor weighs about 0.5 kg). Commercially available motorized car jack specifications studied to make this decision[6].This is further supported by another project paper which mentions “mechanical advantage of the system, results in the output force of 44.175 kN is sufficient to lift the maximum load of the jack which is 20 kN (2000 kg)”, sourced from [3]

The other open point which needs validating during the prototyping phase is the duration taken to lift given the wattage (and torque rating) of the motors is not very high (<10 N-m). Since a commercially available consumer car jack takes 2 minutes for lifting up 16.5 inches [6], with a 8 inch lift height and an allowance of 2 minutes, we should still be able to produce a viable solution for this problem. Existing literature though supports this is a possibility. Quote “The motor is from used car power window motor. It supplied 5.877N.m torque which is high enough and suitable for the project”[5] .

Next steps

The development of the proposed innovative car mobility device represents a crucial advancement in addressing the limitations of existing car jacks. To transition from the conceptual stage to a functional prototype, a series of systematic steps will be undertaken.

1. Testing**:** The initial phase involves rigorous testing of the four scissor jack units. The testing protocol will assess their lifting capacity, stability, and synchronized operation. This involves lifting various vehicle models, adjusting load conditions, and evaluating the performance under different scenarios. Testing will also consider the impact of the motorized scissor jack design on the vehicle's stability during lifting and short-distance movement. The goal is to achieve a lifting process that is not only efficient but also safe and secure. Significant body of literature exists to refer to, in order to get an idea of comprehensive testing that is required to be done. [4]

2. Sources of Error: Identifying potential sources of error is essential in refining the proposed solution. Variations in vehicle weight, uneven terrain, and unexpected mechanical issues may impact the performance of the scissor jack units. The testing phase will systematically introduce these variables to identify potential challenges and develop strategies to mitigate them. Additionally, factors such as battery life and remote control reliability will be scrutinized to ensure consistent and dependable operation.

3. Future Improvements: Based on the testing outcomes, the next steps will involve iteratively refining and enhancing the design. Modifications may include adjustments to the scissor jack units for improved load distribution and stability. The integration of smart sensors or additional safety features may be explored to enhance the overall reliability of the device. Future improvements will also consider user feedback and address any usability concerns to make the device more intuitive and user-friendly.
4. Regulatory Approval: Given the nature of the proposed car jack as a potentially transformative tool in the automotive industry, seeking regulatory approval is crucial. Compliance with safety standards and regulations will be thoroughly examined. The device's integration with the car's battery raises considerations regarding electrical safety and compatibility. Collaborating with relevant regulatory bodies and seeking approval, such as from the National Highway Traffic Safety Administration (NHTSA), will be a pivotal step to ensure the product's legality and safety.

These steps are imperative for progressing from the conceptualization of the proposed solution to a refined and market-ready car mobility device that addresses the current limitations of car jacks.

Design considerations

1. **Portability**: the entire solution including all four jacks should fit into a self-contained box that is at most 1’ by 1’ by 1’ in size.
2. **Ease-of-use:** A typical car driver should be able to use with minimal effort: should not involve opening the hood, or require any complex assembly. It should only involve setting the mechanism below the car’s jacking points and connecting it to the car’s battery terminal [1]. Once connected, the jacks can be placed underneath the vehicle’s jacking points and the included button can be pressed to extend or lower the jack.
3. **Safety**: There also are reports on car jacks which lead to a serious number of accidents. “A specified jack purposed to hold up to 1000 kilograms, but tests undertaken by Consumer Affairs has revealed that is fails to work after lifting 250 kilograms and may physically break when it has a weight close to its 1000 kilograms capacity” [5]. This illustrates that many tend to jacks fail when pushed to their rated max capacities, which is a major hazard since the public cannot be expected to follow the guidelines too strictly. The learnings from these papers are taken into account in the design, making sure that the tolerances are not dangerously tight.
4. **Affordability**: should cost less than $1000 to start with, and ideally offered as an add-on especially in the used car sales process. With scale, and with potential partnership with insurance companies, local authorities, etc., there can be subsidized prices for the user as well, in future. From this perspective, the designs such as a car jack that is built into the car as or as an add-on connected accessory were considered and rejected. The project is targeting to attenuate the human effort and to produce a completely unique screw jacking system that's directly fitted to the vehicle border The intrinsic jack is driven by the electrical power supply from the 12-volt automobile battery[1].

5. **Balanced design**: Compromise between speed of operation versus complexity of the set-up/mechanism: setting this up and lifting the whole car should not take more than 3-5 minutes, followed by another minute to push the car to the side of the road. At the same time, the mechanism (power system, motors, wires, etc.) should not be very specialized or complex to repair. Modular design with replaceable parts is to be the motto.

6. **Scalable architecture** that can be expanded to address other customer segments: Though car driver is the main focus, with few modifications, this should be able to be extended for usage by family-owned and small auto workshop owners, or workshops in densely populated areas where cars can be temporarily held in narrow spaces and maneuvered easily and tow-truck companies.

1. **Reliability**: When existing project literature is referred to for getting inputs on analysis and reasons for the failure of a typical jack, it emerges that the mechanism is very reliable and it is the usage errors that cause failures to a very large extent. Quote "...top 4 highest Risk Priority Numbers (RPN) obtained from the analysis said that the jack failure is caused by the following 4 potential causes of failure:

a. Insufficient gear engagement, jack components failure, excessive load applied

b. Misalignment of jack with vehicle body frame, operation done on uneven road

c. User mislead with the safety precaution procedure during jack operation

a. Difficulty of aligning the vehicle body frame to slot into top bracket groove" [2][1]

[1] A hydraulic design was considered but after examining the complexity, in addition to weight and power requirements as well as possibility of fluid leakage over time (since the device will be rarely used and will have extended periods of idle time when stored in the boot), this was discarded. From this reference, it can be concluded that to lift a 12.3kg car, the force at the piston needs to be 45N, which in turn means that for a real-life car which weighs much more, the force required cannot be supplied for 4 jacks at the same time from the car battery terminal. [7].

Design diagrams and simulation of stress

Figures 1 to 3 are stress test analyses of a CAD model of my design. The colors are ordered Blue, Green, Yellow, Red, going from showing the least to most stressed areas, respectively.

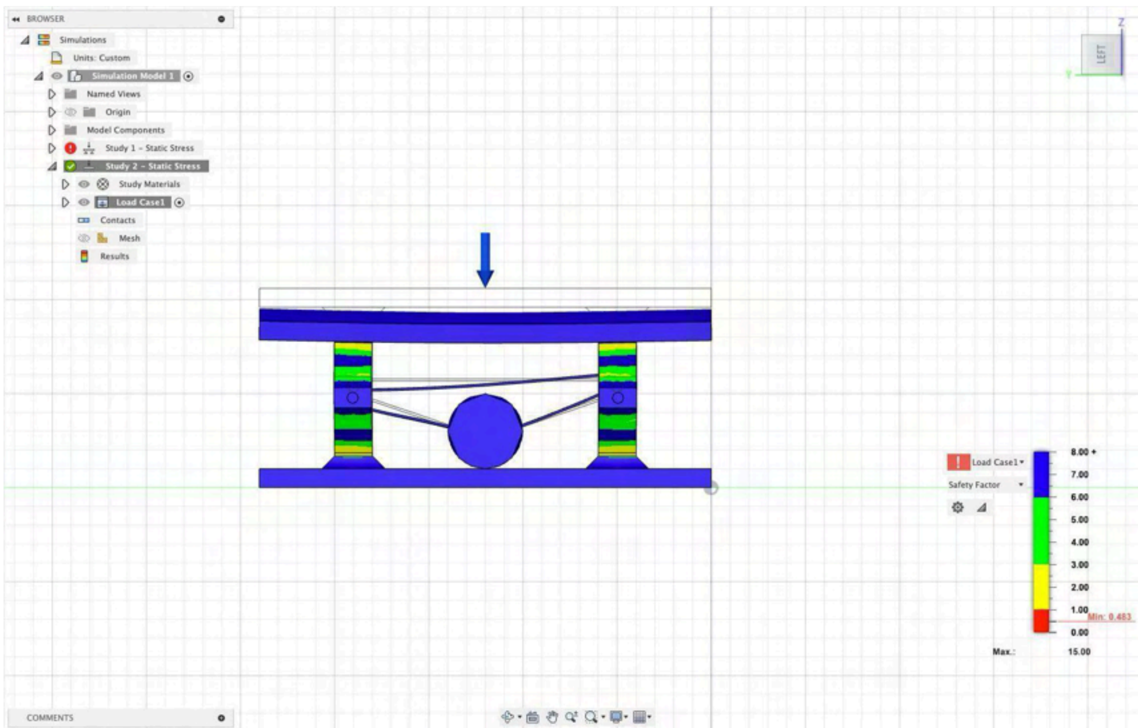

Figure 1: Front-facing view of the jack, with 9800 N force pushing down as indicated by the arrow

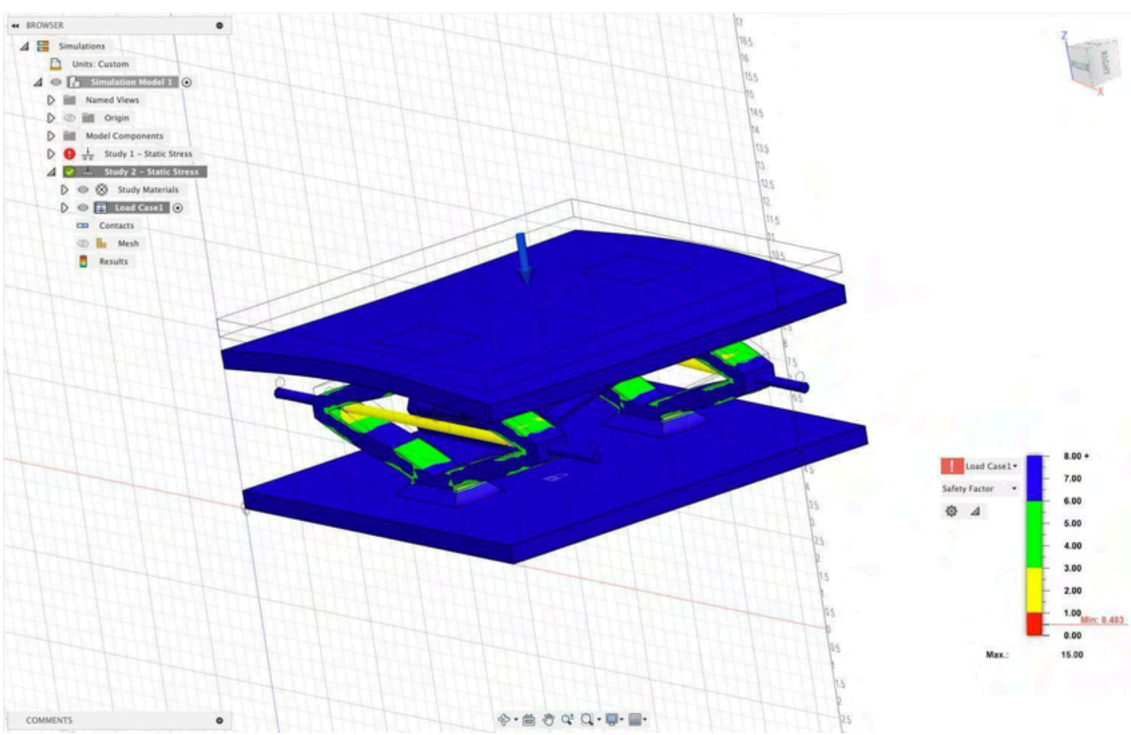

Figure 2: Isometric view of the jack, with 9800 N force pushing down as indicated by the arrow.

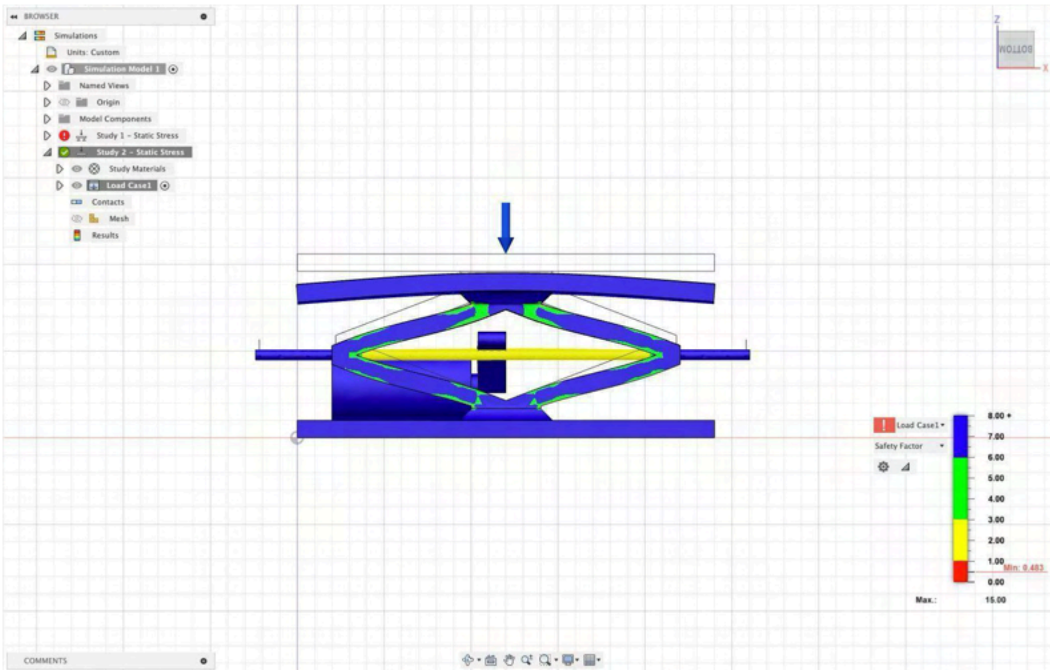

Figure 3: Side view of the jack, with 9800 N force pushing down as indicated by the arrow.

The following are hand-drawn designs of the final jack, showing the different components of the jack as well as the mechanisms used to lift the car. Labeled are the belt, motor, hinges, wheels, and overall dimensions of the design. Figure 6 details the main belt mechanism, showing how it fits on the bolt as well as the ribbed features that allow it to rotate the bolt.

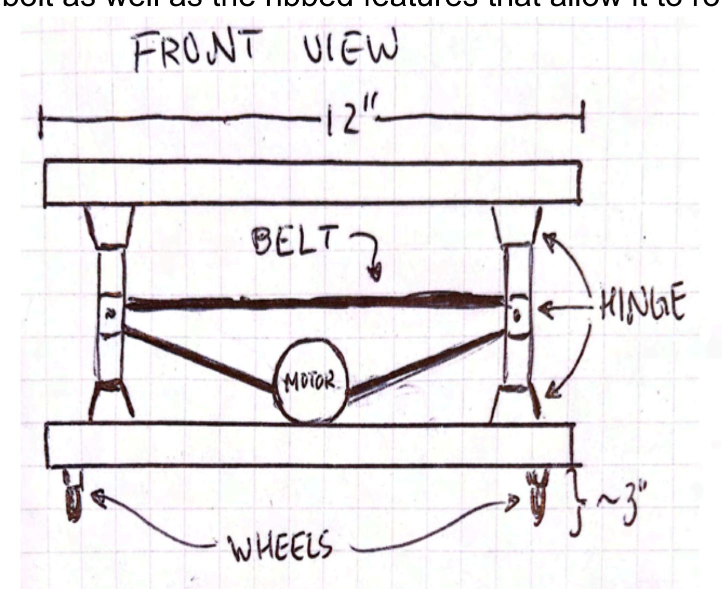

Figure 4: Front view of the mechanism without any pressure on top.

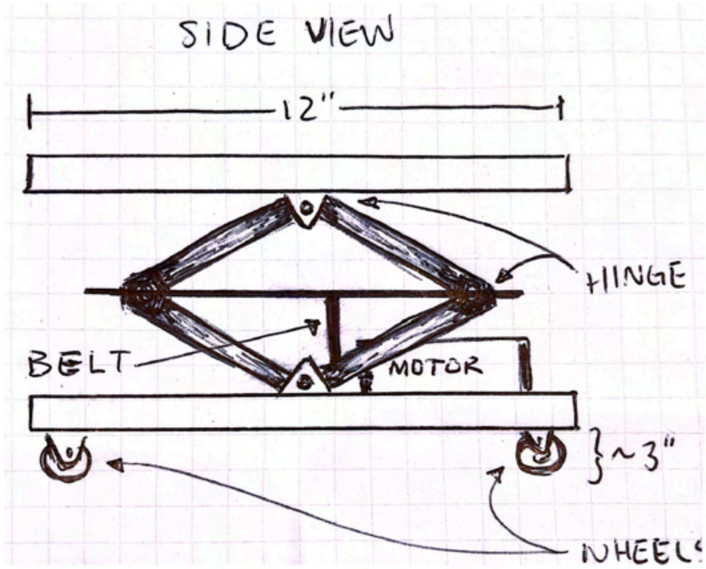

Figure 5: Side view of the mechanism without any pressure on top.

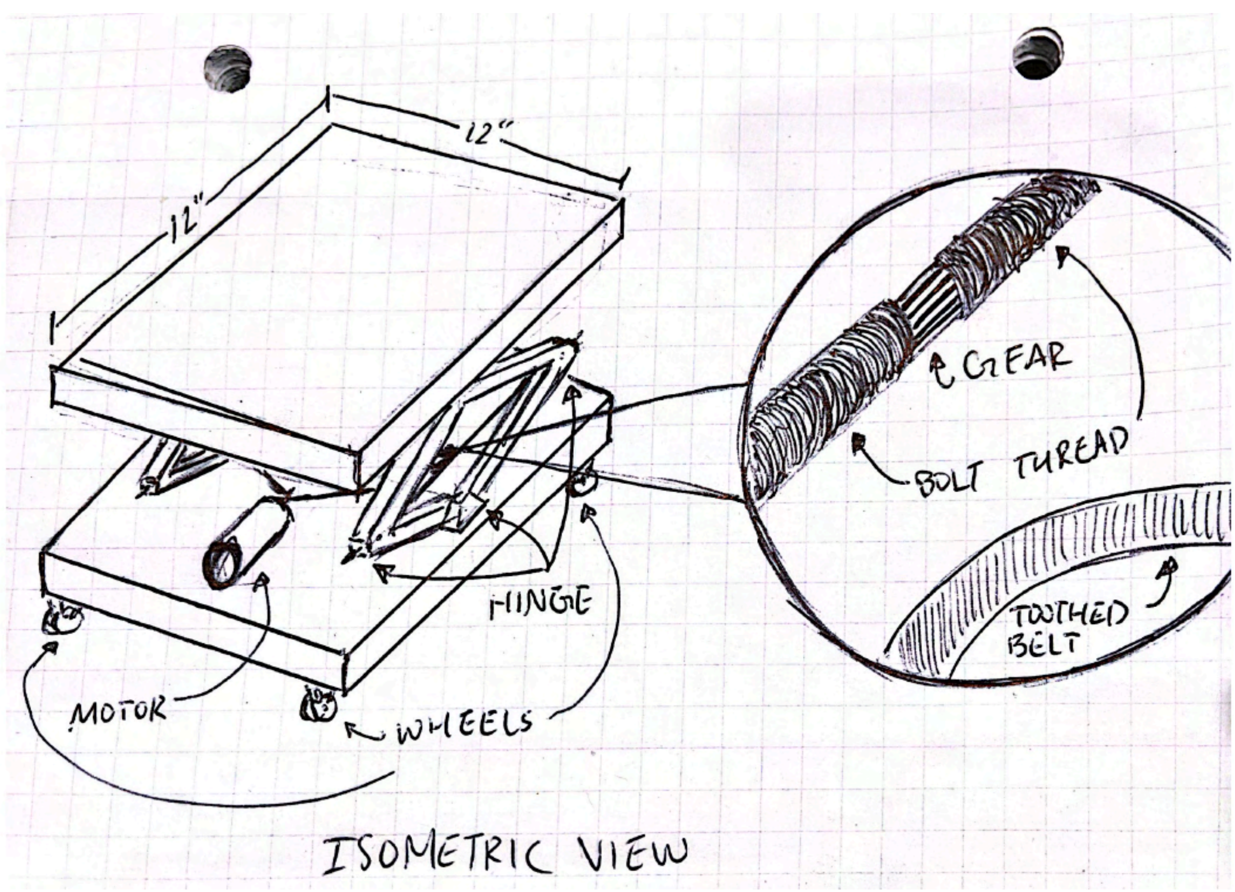

Figure 6: Side view with details of gear and lift mechanism that utilizes thread on the bolt which locks with a toothed belt to create a positive drive (and avoid slippage).

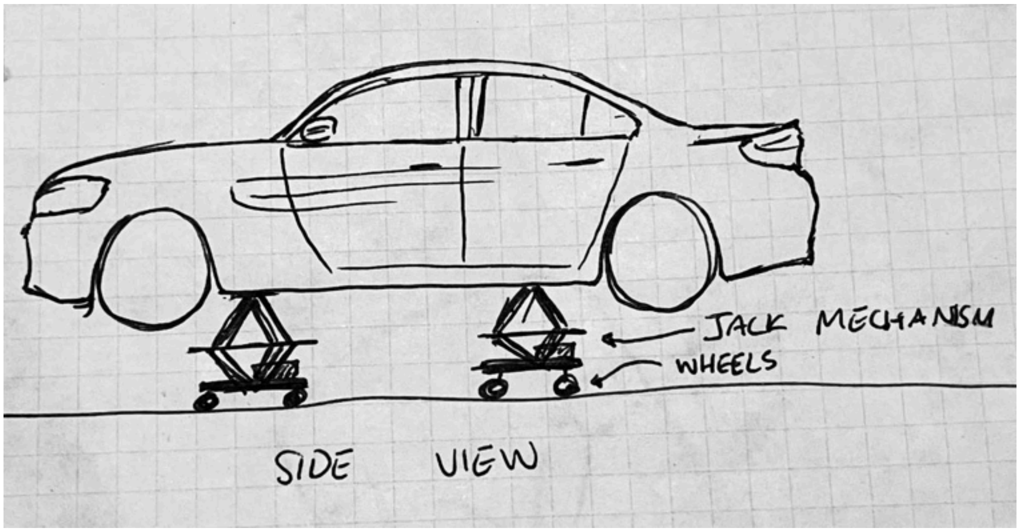

Figure 7: Side view with details of all four jacks (two visible) working in conjunction to lift up the sedan including the wheels on the jacks.

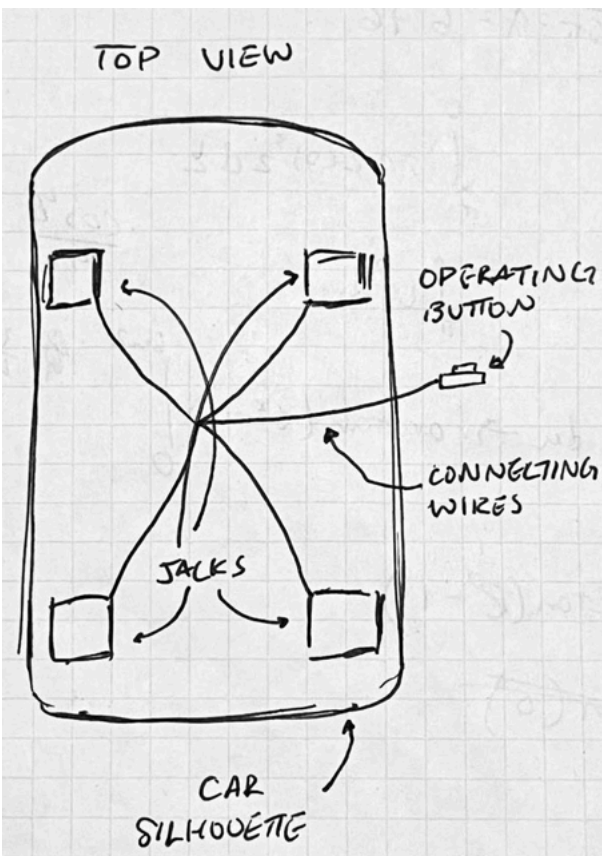

Figure 8: Top view with details of all four jacks lifting up the car as well as the wires connecting the four jacks in order to control the lift of the car.

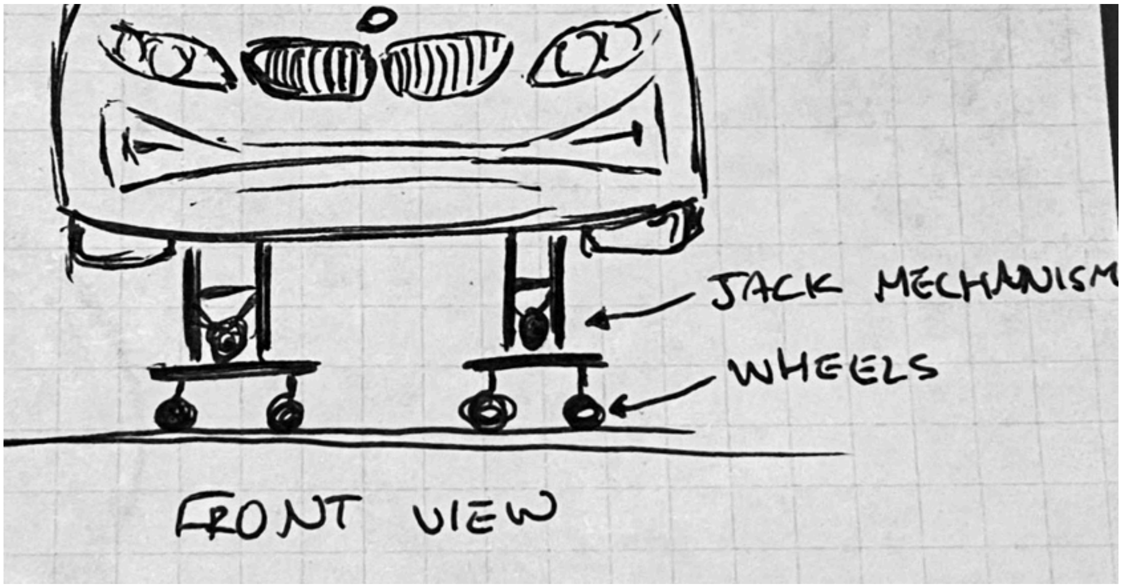

Figure 9: Front view with details of all four jacks (two visible) lifting up the car including the wheels on the jacks.

Project Outlook

The envisioned car mobility device presents a transformative solution to the challenges posed by traditional car jacks, offering a novel approach to vehicular maneuverability in emergency situations. The project outlook encompasses various facets, from cost considerations to potential benefits and the target audience.

Cost: The estimated cost of the proposed car mobility device is a critical aspect of the project outlook. Initial projections indicate an approximate MSRP of $1000 for the first version of the product. This cost accounts for the integration of advanced scissor jack units, motorized controls, and the necessary electronic components powered by the car's battery. While this places the device in a higher price range compared to conventional car jacks, its multifunctionality, motorization, and potential lifesaving applications contribute to its perceived value.

Benefits: The benefits derived from the implementation of the proposed solution are manifold. For individual consumers, the device provides a convenient and efficient means of relocating a vehicle during emergencies without the need for external assistance. This can be particularly advantageous in scenarios such as roadside breakdowns or accident sites, where swift vehicle movement is essential for safety. Furthermore, the motorized scissor jack design minimizes physical exertion, making it accessible to a wide range of users. Beyond individual consumers, the device extends its utility to businesses involved in vehicle maintenance, recovery services, and roadside assistance. Mechanics can leverage the enhanced maneuverability to streamline their operations, reducing work time and increasing efficiency. Roadside assistance and recovery services stand to benefit

significantly, as the device expedites the process of moving damaged vehicles off the roads, thereby minimizing traffic disruptions and enhancing overall road safety.
Target user segment: The target audience for the proposed car mobility device encompasses a diverse range of users. Individual consumers, especially those with a need for on-the-spot vehicle relocation during emergencies, constitute a primary demographic. This includes drivers facing unexpected breakdowns or accidents, where the device's quick and motorized operation becomes indispensable. Professionals in the automotive industry, such as mechanics and recovery service providers, form another key audience. The device's potential to streamline their operations and enhance overall efficiency positions it as a valuable tool for workshops, recovery crews, and roadside assistance teams. The user-friendly nature of the device makes it accessible to both seasoned professionals and those with limited technical expertise.

Conclusion

In conclusion, this research paper has explored the imperative need for an innovative car mobility device, driven by the altruistic goal of enhancing user-friendliness in car jacks. The proposed solution, featuring four portable, motorized scissor jack units powered by the car's battery, represents a significant leap forward in addressing the limitations of existing models. The envisioned device not only lifts vehicles effectively but also enables short-distance movement, offering a practical and efficient solution for emergency scenarios.

The development of this innovative car jack is grounded in the earnest desire to assist individuals in distress, stranded on the side of the road. By eliminating the need for engine ignition during vehicle relocation, the proposed solution provides a valuable tool accessible to a diverse range of users. Its potential impact extends beyond individual consumers to businesses engaged in vehicle maintenance and recovery services, where its efficiency promises to streamline operations and increase overall productivity.

The next steps in the project involve rigorous testing, identification of potential sources of error, and iterative design improvements. These crucial phases aim to refine the proposed solution, ensuring its safety, reliability, and user-friendliness. The project outlook emphasizes the estimated cost, benefits, and the diverse target audience, positioning the device as a valuable investment for both individual users and professionals in the automotive industry.

As we embark on the journey from conceptualization to a refined and market-ready product, regulatory approval will be sought to ensure compliance with safety standards and regulations. This step is essential in establishing the device as a legal and safe solution for vehicular maneuverability.

The proposed car mobility device represents a promising innovation with the potential to reshape the landscape of emergency vehicle relocation. By addressing the limitations of existing car jacks and current emergency services, this device allows for improved safety on the road due to a more efficient process of relocating crash damaged cars. This device can also benefit mechanics and service stations, as it provides a solution overall better than existing examples, allowing for quick and low-effort relocation of vehicles. As the development progresses, the impact of this transformative tool on individual users and the automotive industry as a whole, holds the promise of a safer and more accessible road environment. Acknowledgements and references further validate the collaborative effort and research depth that underpin this endeavor.

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