ROTARY INVERTED PENDULUM

SOCIAL CONTEXT OF AUTOMOTIVE ENGINEERING 'FAILS'

A Thesis Prospectus
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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

“This is the perfect example of why I hate the f*cking automotive industry,” grumbles one disgruntled mechanic (Real Mechanic Stuff, 2023). He has been upset by a belt tensioner. Specifically, a long bolt on the belt tensioner which cannot be unscrewed, as the space it would unscrew into is currently filled with a large section of the car’s bulkhead. My problem initially extends from a series of complaints made by mechanics and auto enthusiasts regarding similar ‘engineering failures’ encountered when servicing vehicles. The origin of those registering these complaints can be difficult to determine, but by accent the majority of the complaints which prompted this investigation seemed to be made in the USA (Real Mechanic Stuff, 2023). The origins of the platforms which were being complained about, however, did vary. Examples include awkward or unnecessary components of design such as bolt lengths or limited access to regularly serviced components like oil filters. The common consequence of all outlined ‘failures’ was that they made some maintenance or modification far more difficult than would be reasonably accepted.

As a mechanical engineering student hoping to work in auto design, I was initially defensive of the criticized engineers, “Give them a break!” I exclaimed, “Cars are so complicated these days”, “Nobody’s perfect”, “If making cars was easy, everyone would do it” and so on, and so forth. It wasn’t until my technical project (A rotary inverted pendulum) had given me a taste of serious design that I realized, even with the growing complexity of cars, that most of these ‘failures’ would be fairly easily caught before any vehicle makes it to even initial physical prototyping. So why do these problems persist past mass production and distribution? This question is the heart of my sociotechnical problem. It is fueled by the growing understanding of ‘good design’ granted to me by my technical project. The goal of my STS project is to understand the social impact of automotive design in the socially and culturally charged automotive industry.

Technical Topic

Throughout the development of this technical project the aim as it relates to the sociotechnical problem is to determine what goes into a good engineering design. My technical project is to design and manufacture a rotary inverted pendulum, meant to serve as a demonstration in lectures and conventions of controls and mechanical principles. Additionally, it differs from most other rotary inverted pendulums in that it must be easily portable. This means that it must be light enough and small enough to be carried, ideally with one hand, over reasonably long distances, multiple times a day. This capstone project differed from other mechanical engineering capstones in that our product was explicitly assigned by our capstone professor, where normally the student would choose a project, and the professor would at most issue an area in which the project must be involved.

This may be different from typical mechanical engineering capstones, but it is very similar to the role engineers and designers would play in a professional setting. Engineers don't so often 'choose' what they make so much as they choose how to make what they have been assigned by their employers. Typically, an engineering design department or firm is told by their superiors or contracted by a client to design a product, along with this request some key criteria and uses for the design are also provided. The key criteria are expanded and codified into customer needs, and then target design specifications are produced. What follows is an iterative process whereby these key criteria are organized and expanded upon, then the team brainstorms as many designs as possible, and ranks them in accordance with the design's ability to fulfill the criteria, and how each design fits into the target specifications. In each new iteration, the best designs are selected and expanded upon, ranked again, and then the next iteration begins. These rounds of brainstorming continue for an arbitrary number of iterations, until an ideal concept is selected.

There can be multiple rounds of concept generation, concept screening, and concept scoring before a single concept is selected. Once a concept has been selected, the team begins on system-level design. In system level design, you develop product architecture, define major subsystems and interfaces, and some preliminary component engineering. Next comes detail design, where part geometry, materials, and tolerances are defined. Only then does a product enter into physical testing. This is a simplification of the design element of a common product design process as defined in Ulrich and Eppinger's Product Design and Development, 7th ed, 2020. Other elements include manufacturing and marketing. These two elements can be handled by other teams, but both will communicate with those working on the design element throughout the entire process, as both work in parallel with the design element. My technical project follows this design process framework, and our team is responsible for all elements discussed, besides marketing, as we aren't designing a product that will be sold.

A major problem presented in designing our RIP to be portable is vibrations. Our product has to be able to rotate very quickly from side to side to maintain the equilibrium of the pendulum, other examples of rotary inverted pendulums solve this by incorporating very large and typically heavy bases onto which the machinery is fastened. This is not a viable solution for our rotary inverted pendulum, as these methods result in a bulk and weight which is unreasonable for a portable example as defined in our technical specifications. Stress analysis is employed to find the natural frequency of several key components of our current design, and weight simulation is used to decrease the inertia of the moving parts, and so the maximum weight of the design can be brought into an acceptable range. Despite these problems, and using the simple design process method outlined earlier, our small 3 man team is on track to design, produce and assemble all necessary physical components within a single semester. The design process employed in our technical project is proof that systems exist which are capable of identifying and eliminating the failures which received criticism.

STS Topic

The internet has no small amount of examples of mechanics or enthusiasts complaining about some inane piece of design on their, or their customer's car. Almost every time they'll blame the engineers, and in the comment section of almost every youtube video, instagram reel or tiktok, you will find an engineer saying it isn't their fault. So who is to blame for these 'engineering fails' in reality? The simple conclusion upon seeing a bolt that's impossible to unscrew or a design that requires you to remove the engine to replace the starter is that the designer simply didn't consider it. My experience with engineering design in my technical project has shown me that design process models do not allow for such errors to go unnoticed. However, the engineers are not the only people who determine the development of a car. When a car company sets out to design a new car, they involve every corner of the company when defining product specifications(Aston). From Stakeholders, Marketing and Cost estimators, to Styling and Manufacturing, everyone plays a part in the production of a new automobile(Vault). After all, car companies are social institutions, only a portion of which includes the actual engineer. The reason these problems persist may lie in social, cultural, political, and economic sectors.

Mechanics love to hate on engineers, and engineers love to blame management, and everyone loves to be very defensive about their skill. With good reason. A mechanic's livelihood depends on their ability to maintain and repair cars quickly and/or cheaply. Similarly, engineers need to be able to do good design in order to survive. In an industry as massive as the automotive industry, problems can ruin the lives of hundreds, if not thousands of people. Knowing how to get problems solved is, therefore, very important. Some terminology. Right to Repair is a blanket term for bills, proposals, memorandums, and state laws which directly address consumer's right to accessible repair and maintenance information/practices for automobiles and automobile systems. In simple terms, it prevents car companies and OEMs from making products that no one else can repair. OEM stands for original equipment manufacturer, they produce non-aftermarket parts or equipment that may be marketed by another manufacturer.

Winner's STS framework says artifacts have politics. This STS project will analyze the politics of the artifacts produced by car companies and original equipment manufacturers (Winner, 1980). I seek to understand how automotive design aspects have social consequences. I hope to document the social outcome of automotive design. I will do this by researching common complaints leveled at auto design on online social forums, and by following the history of regulations restricting automotive design in the automotive aftermarket, such as 'right to repair'. I seek to identify at least one specific platform or manufacturer which has incurred well documented social unrest through their automotive design. I will then use the knowledge of automotive design regulation to discover what can be done to fix the problem. The final deliverable of my STS project will be a list of known problems which have been blamed on automotive design. Alongside each complaint there will be the existing procedures and regulations which are responsible for solving the problem.

Car companies produce increasingly complex cars. Third party services such as independent mechanics and service centers struggle to react to this increased complexity without the necessary specialized knowledge. The Motor Vehicle Owners' Right to Repair Act, referred to as Right to Repair, is the name for several related bills proposed to the United States Congress beginning in 2001. These bills all sought to require automobile manufacturers to provide the same information to independent shops as to dealer shops, and have been adopted at the state level in several forms since the initial senate proposal in 2001. Several bills enacted in Massachusetts from 2012 to 2013 became the basis for a memorandum of understanding signed in early 2014 by several large automotive associations which would commit vehicle manufacturers to meet the requirements of the Massachusetts law nationwide. Note that this is not an enforceable law, what enforcement there is is done through a panel of representatives established by the original signing parties (Memorandum of Understanding, 2014). Note as well that in order to be in compliance with the 2014 agreement, all an OEM has to do is provide information which can be accessed.

Conclusion

This sociotechnical problem started in the comment section of a video about engineering fails in the auto industry. One comment, by a self-proclaimed mechanical engineer working in automotive design, stated that almost all of the 'engineering fails' are identified before commercial sale, and that marketing or managers simply deemed it unnecessary to fix them. This was an insubstantial claim made by an anonymous person, but the scenario proposed was feasible enough to be enticing. My work on the technical project convinced me that the reason for the 'engineering failures' was unlikely to stem from a technical or scientific incapability. The STS project introduced the right to repair to me and allowed me to consider the efficacy of the scenario, and greater motivators of social, political, and legal origin. A secondary purpose of the

STS project is the collected list of known problems and the ways in which they can be addressed. I hope to provide the reader with both of these things.

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