Design, fabrication and commercialization of a powered ramp for power wheelchairs

Nassif Rayess, Ray Okonski, Molly Laird, Evan Jeffries and Austin Ross
Department of Mechanical Engineering
University of Detroit Mercy
Detroit, MI 48221
Email: rayesna@udmercy.edu

Abstract

Power wheelchair users are often faced with having to negotiate stairs, which causes an unsafe situation for both wheelchair occupant and helper. This situation is fairly common in households as well as businesses that are exempt from ADA regulations. In cases of stairs consisting of few steps, there are foldable ramps that one can deploy and roll the wheelchair on. However, if the number of stairs exceeds three or four, the inclination could cause serious problems in terms of the force required as well as tipping stability. This paper documents the design and fabrication of the Wheelchair Escalator, a solution that incorporates a temporary rail structure and a platform that rides on the rails and gets towed up and down using a common winch. The Wheelchair Escalator story is presented from the varying perspectives of the students, supervising faculty and external advisors.

Introduction

Senior design projects are common staples in engineering curricula. There are a number of contexts in which these projects can be undertaken. There are those sponsored by industry and afford students a credible context mirroring engineering practice. These projects also provide an endpoint for student engagement at the point of the delivery of the project. There are projects that are entrepreneurial in nature, in which students either seek or are provided with a market need and tasked to innovate a solution. These projects also provide an excellent context. However these projects do not provide a clean end point for student involvement as is the case when students deliver a project to an industry sponsor. Technology commercialization[1,2] of student projects, namely the question of what to do with a technology developed by students beyond the end of the semester and the issuance of grades, is a vexing problem. It is the rare case when one or more of the student team members decide to pursue the entrepreneurial route. More often than not, the student teams begin pursuing professional corporate careers and the technology becomes abandoned or falls to the University or the faculty to develop it further.

The dilemma of what to do with promising technologies developed by engineering student teams in cases when the students have moved on is a common one in entrepreneurial – type projects. This paper describes one project that seems to have escaped the common fate of abandonment. This paper begins with a description of the client and the client need, then describes the technology developed by the senior design class. The paper then moves to describe the process of commercializing that technology, a process that involves a new group of students, faculty members and external sponsors. In this case this external sponsor is a retired CEO of a small business and an entrepreneur in his own right. The differing expectations and modus operandi of the various groups were a source of difficulties and these will be discussed in the body of the paper.

The Client

The client was a retired veteran who had become disabled due to a severe case of peripheral artery disease. The disease ultimately led to the amputation of both legs which confined him to a wheelchair. The client lived in an apartment that is slightly below grade level requiring him to navigate a short flight of stairs, seven steps to be exact. As the apartment building was not equipped with an elevator, his only means of coming and going is to be carried up the stairs in his manual chair by members of his family. The client expressed a desire to be able to use his power wheelchair outside his apartment, as it is far more convenient and comfortable. However the power wheelchair, with its excessive weight, could not be easily carried up and down the stairs. Thus the client asked the student team to design a solution that is acceptable to the landlord, can easily be deployed, and allow him to go up and down the stairs using his power wheelchair.

The Team

This project was undertaken in the course of the senior design class by an interdisciplinary, intercollegiate student team consisting of three mechanical engineering students from University of Detroit Mercy, two mechanical engineering students from Ohio Northern University and three nursing students from University of Detroit Mercy. The mechanics of that collaboration is discussed in reference 3. The team first met with the client in September 2014 and produced a first version in April 2015 of what has come to be known as the Wheelchair Elevator. A detailed description of the design is given later in this paper. As is the case with most student generated projects, the initial version was a good proof-of-concept but was fairly removed from being commercially viable. Following the final presentation in April 2015, an external sponsor (the second author in this paper) expressed the desire to hire mechanical engineering co-op students to further develop and refine the project. Two students were hired (the third and fifth authors in this paper) and worked under the supervision of two faculty members (the first author in this paper and Dr. Darrell Kleinke who is the ME Chair at UDM). Throughout the process the team was helped by the mechanical engineering technician at UDM.

The Wheelchair Escalator - Version 1

The intercollegiate senior design team[4] was faced with the task of moving a power wheelchair and occupant, having a combined weight of over 500 pounds, up a steep flight of stairs (seven steps). The prototype solution, shown in figure 1, consists of a slightly modified eight-foot wheelchair ramp, a trapezoidal platform with wheels, and a winch and cable system. The trapezoidal platform is shaped such that wheels installed on the inclined surface can ride up and down the ramp while the two parallel surfaces remain horizontal. The top surface is where the wheelchair rests while the bottom horizontal surface allows the platform to rest on the ground. The ramp is modified by creating a bracket in order to trap the wheels of the platform for safety purposes. The winch is installed on the bottom of the platform and the cable is attached to the top of the ramp. Thus, as the winch retracts, the platform/wheelchair is towed up the ramp. As the winch reverses, the platform/wheelchair combination is lowered slowly under gravity. The winch is controlled using a pendant by either the wheelchair user or by an external helper. A number of sensors are used along with the programmable logic controller to ensure safe operation of the device.

As the device was put together and tested in April 2015, various issues with the design became apparent. The first issue pertains to the fact that the ramp covered the stairways and was at such a steep angle that the stairs were no longer accessible. Another issue relates to the flexibility of the ramp. Portable wheelchair ramps are made in order to be light enough to carry and foldable in order to be handled. The foldability and light weight introduced a significant amount of structural flexibility and caused a number of issues. The most dangerous of which was the fact that the platform was prone to getting stuck on the way down. Under operating conditions, this could lead to significant safety concerns. Significant design and development effort took place in summer 2015 in order to remedy the two aforementioned problems.

Figure 1 – Initial version of the Wheelchair Escalator, designed and manufactured by an intercollegiate team of ME students from UDM and Ohio Northern University. Photos courtesy of John Fernandez and Kathryn Skobrak.

The Wheelchair Escalator - Version 2

Two rising sophomores co-op students, hired for the summer of 2015, worked under the direct supervision of faculty members and external sponsors in order to redesign the Wheelchair Escalator in such a way as to remedy the two problems of stairway accessibility and lack of stiffness of ramp. The first design change involves replacing the ramp with a self-supporting rail structure made out of large thin-walled aluminum rectangular tubing, see Figure 2. This self-supporting rail frame is designed for fairly quick assembly and disassembly. With the rails located on the outside edges of the steps and with nothing in between, the stairway accessibility problem was solved. Furthermore, the rail frame/assembly was design to have sufficient stiffness that any wedging issues are resolved as well. The wheels have been replaced by wheel assembly pods consisting of three wheels each which contacted the rail at the top and bottom surfaces and on the inside surface. The top and bottom wheels serves the purpose of carrying the load and preventing tipping while the inside wheel ensures that the platform tracked straight without side to side motion and/or wedging.

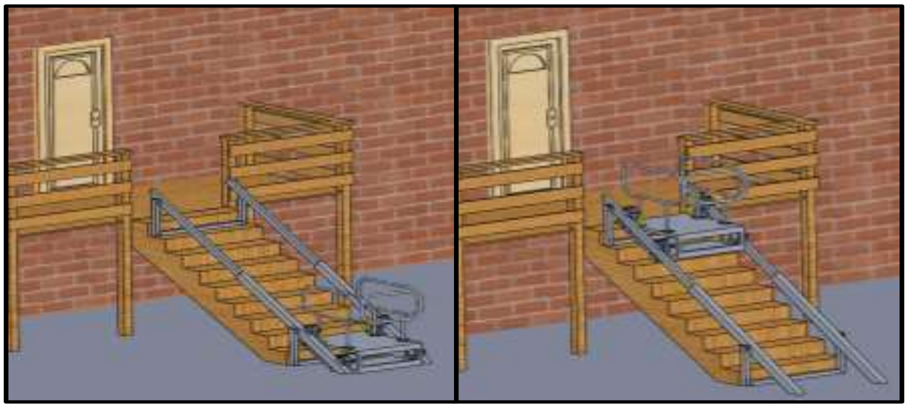

Figure 2 – The second iteration of the Wheelchair Escalator. Rendering images on top. Actual prototype on bottom.

Assessment

The construct employed in this this endeavor involves: a promising technology, engaged faculty, students available for employment, and a sponsor (either external or internal). In the case of the Wheelchair Escalator, all those factors were met. Thus, this project is assessed from a technology perspective, faculty perspective, student perspective and a sponsor perspective.

Technology Perspective

The Ramp-Escalator fulfills a particular market need that carries with it a valuable proposition. In the space of mobility devices and solutions, the ramp escalator fills an important void between basic ramps that are able to negotiate one or two steps and full-fledged stair lifts able to negotiate large stairs but require installation and thus become a fixed infrastructure. The ramp escalator is fairly mobile, fairly light, and fairly easy to assemble and disassemble yet negotiate large stairs. So, from that perspective, the Wheelchair Escalator fills an important gap in the market and is thus of sufficient commercial viability to warrant further development.

Faculty Perspective

For a faculty member who is interested in technology development and transfer, this type of project work is ideal. Regardless of business interests, this type of work carries sufficient career development benefits to warrant engagement. For one, the technology being developed could lead to intellectual property that will potentially net the faculty member a patent application and/or publications. Also, there could be access to outside funding, particularly from foundations in cases where the nature of the project dovetails with a foundation's mission. Furthermore, this type of work, when it involves undergraduate students, provides the faculty with a valuable mentoring opportunity. This is particularly the case when the undergraduate students show interest in entrepreneurship and product development.

There are, however, some problematic aspects of working with undergraduate students on commercializing products, particularly ones that are externally sponsored. Much of the problems stem from a mismatch in expectations between external sponsors and academia. Generally, external sponsors are either successful entrepreneurs or ones who have been successful in business, rising to fairly high levels in their respective corporate settings. Their success is related to them being result-driven individuals that expect timely performance and who are able to secure and allocate the needed resources to achieve it. Universities, at the undergraduate engineering setting, cannot be result-driven but are instead process-driven as they shepherd and guide young individuals through late adolescence and into early professional adulthood. This process-driven education of young engineers often requires the subjugation of desired engineered artifacts in favor of providing a positive, nurturing environment for students particularly at the early stages where student retention is of concern. A faculty advisor must find a way to achieve the desired result for the sponsor while giving the students the needed time and space to develop. This, coupled with the overall limited resources at small primarily undergraduate institutions, invariably leads to project delays and frustration.

External Advisor/Sponsor Perspective

An external advisor, coming into a situation where a university is attempting to commercialize a student-generated product or process, must be prepared to face a number of unanticipated obstacles. These real obstacles often stand in stark contrast to the firmly stated positive verbal support to the contemplated program.

One culprit is the inadequate funding and limited resources which relegate the significant effort required to the status of "extra responsibility" for the faculty and staff. It is not uncommon to have engineering faculty and staff mired in tasks such as shipping, receiving, purchasing etc. which are time consuming and disruptive efforts.

Another culprit is a lack of clarity of purpose. A clear definition of the project is absolutely mandatory as too often, the scope of the original project gets expanded in order to meet new conditions and/or to become a more comprehensive solution to the original goal.

An external advisor can expect the original timetable/schedule of dates for completion of milestones, as established by the group, to almost never be adhered to. Faculty and students are subject to unpredictable changes in their schedules which almost always have a higher priority.

Helping develop and execute a business plan is key to the success of a product development project. At a small university, a successful plan will almost always require the cooperation of different departments and or different schools. For this project, coordination with the law school was critical to filing the patent applications and to provide an analysis of the potential conflicts with existing patent holders. This could also be a source of delays and frustrations. The external advisor can be of great service if he is able to coordinate the efforts of these various departments.

Student Perspective

The work of redesigning the Wheelchair Escalator was very rewarding as it involved redesigning the prototype and deciding on the features to keep and those to change or discard. It was also interesting to work with both the external advisor and the faculty. Reconciling the vision of the external advisor against the directives of the faculty advisors proved to be a challenge as these were conflicting at a number of points in the design.

One of the lessons learned was to produce the simplest designs that were easy to manufacture but still operate properly and achieve the desired function. Another lesson was to mind the small details, as the smallest part of a product can have an outsized effect if it is not working properly.

The entire process allowed the students to learn how a product is made and how much thought is put into small aspects of a product. At times, the students were given a bit too much freedom with the design to the point that "we had no idea where to even begin".

One of the favorite part of the project was the manufacturing. The ability to see one's idea be brought to life by one's own hands was an amazing experience. Manufacturing also made the students appreciate the amount of work and effort that goes into making even the simplest of parts. Moreover, it helped to illustrate the impact of design on the manufacturing of a product. Namely, keeping the manufacturer in mind is very important in design work.

One of the student authors concluded by saying: "Although there were frustrating parts during the design, my professors were able to stay supportive throughout the entire project. Many mistakes were made, but they were a huge reality check that helped me learn. Overall, my experience this summer is irreplaceable. The amount of hands-on learning was something that could not be taught in a classroom."

Conclusions

Commercializing a product known as the Wheelchair Escalator is underway at University of Detroit Mercy. The process starts by identifying a promising technology, generally developed by the senior design class. In the majority of cases, the students who originates the design are not interested in pursuing it and opt to begin their careers. The construct presented in this paper involves engineering co-op students working under the directions of faculty advisors as well as external advisors. The role of the external advisor is to provide venture creation expertise and seed funding. In general, all constituents felt that this can be a very worthwhile experience while pointing out some difficulties that must be dealt with.

Acknowledgement

The authors would like to acknowledge the contributions of the senior design team who are responsible for version one of the Wheelchair Escalator: John Fernandez, Kathryn Skobrak, Amber

Hauer, Jared Marr and Alberto Pacheco. That team was supervised by Drs. Darrell Kleinke and Molly McClelland from UDM and Drs. Vladimir Labay (on Sabbatical from Gonzaga University) and J.D. Yoder from ONU. The work would not have been possible without the manufacturing help of Christopher Sassak.

Financial support was provided through a Kern Entrepreneurial Engineering Network (KEEN) grant and through the philanthropic giving of Mr. Ray Okonski.

Bibliography

1. Nelson, G., Butler, G. and Williams, B. (2009, June), *A Model for Technology Commercialization: Mississippi State University*, Paper presented at 2009 Annual Conference & Exposition, Austin, Texas. https://peer.asee.org/4634
2. Felse, A. and Kourkine, I. (2014, June), *A Sequence of Technology Commercialization Courses for Science and Engineering*, Paper presented at 2014 ASEE Annual Conference, Indianapolis, Indiana. https://peer.asee.org/19995
3. Rayess, N. E., Garner, B. A., Kleinke, D. K., Blust, R. P., Jordan, W. M. and Dougherty, E. J. (2014, June), *Intercollegiate Student Design Projects: Lessons Learned by Four Universities*, Paper presented at 2014 ASEE Annual Conference, Indianapolis, Indiana. https://peer.asee.org/20690
4. Fernandez, J., Skobrak, K., Marr, J., Hauer, A., Pacheco, A. (2015, April), *Final Report of Senior Design Class*.