Thesis Portfolio

Computer Science and Open Source Software: Development of a Micro-endowment Platform for a Nonprofit Organization
(Technical Report)

Social Entrepreneurship Priorities in the Hardware, Software, and Computing Systems Industry: A Case Study on Elon Musk
(STS Research Paper)

An Undergraduate Thesis
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment
Of the Requirements for the Degree
Bachelor of Science in Computer Science

By
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Sociotechnical Synthesis

When it comes to social issues, there is oftentimes a dichotomy between those individuals and groups whose mission is to solve these issues and those with the technical and software skills necessary to craft full-fledged solutions (Tucker, Morelli, & Lanerolle, 2011). Both of my thesis projects address both sides of this dichotomy and discover ways to bridge this gap. My technical project provides a social organization with a tangible software product developed by a team of student engineers. My STS research is a case study on a social entrepreneur that uncovers methods in which entrepreneurs are attempting to solve mankind's most pressing problems.

My technical thesis project is the collaborative development of a web application that enables users of the nonprofit organization giv2giv to make and monitor donations to charities of their choice. There are two major positive outcomes from this project. First, the student development team learned professional software development skills while working with a real world customer. Second, the team was able to deliver a fully functional product to a nonprofit organization that lacked the technical resources necessary to develop it internally. This project directly addresses the social issues dichotomy by wedding a technically skilled team with a socially minded organization in order to increase charitable donations.

The STS portion of my thesis determines some of the social entrepreneurship practices present in the modern-day technology industry. This research is a case study on the entrepreneur Elon Musk that suggests he has focused on creating low-cost, sustainable solutions to major environmental issues. All three of his current ventures utilize reusable technology and energy sources to lessen mankind's impact on the environment. His companies

reveal the importance of balancing solving social issues and remaining profitable in order to achieve long-term success. These findings offer meaningful insight on some of the technology-focused methods that a successful social entrepreneur is using to attack pressing social issues.

Both my technical and STS projects accomplish the goal of directly and indirectly addressing the division between individuals with technical skills and those focused on social problems. My technical product provided a nonprofit with a product that helped it solve a social issue, while my STS research added tangible findings of how social entrepreneurs are answering current social concerns. Since studies of social entrepreneurship are in the early stages, researchers wishing to augment these findings should examine work being done on issues other than sustainability. There are scores of different social problems that need to be solved and understanding how social entrepreneurs in those spaces are structuring their knowledge and resources may help shed more light on the social entrepreneurship priorities in the technology industry.

I would like to sincerely thank all of those who helped contribute to the development of these projects and my undergraduate thesis. Thank you to my technical and STS advisors, Professors Aaron Bloomfield, Patricia Click, and Jack Brown, all of who were integral in the success of this thesis. A sincere thank you to my team's technical mentor, John Feminella, and our enthusiastic customer, Michael Blinn. Last, but certainly not least, thank you to my development team group members, Rebecca Boswell, Mark Cheung, Loren Fryxell, Eric Tsai, and Jason Ya.

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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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Development of a Micro-endowment Platform for a Nonprofit Organization

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ABSTRACT

Giv2Giv is a new, nonprofit organization whose goal is to create a web visualization platform for its users to make and monitor micro-endowment donations to charities of their choice. It provides a significant impact for charitable orga- nizations by aggregating many small contributions from a community of donors. Through social media integration, giv2giv allows current donors to advertise their activities within the giv2giv ecosystem in order to encourage others to donate as well. The web application provides users the opportunity to organize their favorite charities into 'pack- ages' that other donors can pledge and contribute to. After a user subscribes to a package, giv2giv manages the monthly deposits from the user and transfers them into an invest- ment fund of the user's choice, allowing the contributions to grow. Every quarter, giv2giv deducts a percentage of the invested money and distributes it to the specified charities. Giv2Giv's emphasis on investing users' contributions di↵er- entiates it from many other organizations in the charitable donations space. Other key components of the giv2giv sys- tem include its transparent nature and usage of open source software. The system's transparency is two-fold. From a user standpoint, donors are able to see exactly how their investments are being utilized and how their donations over time will benefit their favorite charities. Operationally, the system's transparency is ensuring that development follows the specific terms and licenses under which the open source software, namely CakePHP, is made available. This paper documents the creation of this novel micro-endowment plat- form.

Keywords

nonprofit organizations, class project, open source software, donations, CakePHP

1. INTRODUCTION

Giv2Giv is a nonprofit organization in central Virginia that aims to give charitable donors their own personal micro-

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trust fund. Its goal is to enable individuals to make small, recurring, tax-deductible contributions to a personal invest- ment account and contribute the earnings over time to the charities of their choice. Introduced at the Charlottesville Start-Up Weekend in 2012, giv2giv is still a growing organi- zation. Two major needs of the company are finding ways to market themselves to the community and providing an easy medium for donor and charity interaction. Giv2Giv decided that performing all of these actions manually is too ine cient a solution to gain much traction in the market. Instead, the organization would rather build an interactive web application with social media integration to facilitate making micro-donations and getting other potential donors involved.

Giv2Giv's original proof-of-concept was a Facebook page and a separate demonstration website composed of a logo and a mission statement. This page lacked the functionality of allowing users to sign up on the site, view individual char- ities, or track and report financial transactions, all of which are crucial components of a fully functioning micro-donation platform. Although this webpage was primarily focused on garnering interest in giv2giv, it lacked the proper function- ality because giv2giv did not have the technical resources to create its desired system. Many nonprofit organizations lack this ability to implement software solutions due to bud- getary restrictions, lack of technical expertise, and need for specialized software systems [9]. Employing the use of open source software can be both a cost-e↵ective solution and al- low for a customized implementation that meets a specific need [2].

The Service Learning Practicum (SLP) course at the Uni- versity of Virginia desires to address these issues that non- profit organizations, such as giv2giv, face. SLP was designed by Professor Aaron Bloomfield to teach students profes- sional software engineering skills through software develop- ment projects for nonprofit organizations [1]. Students are placed in groups of three to six at the beginning of the school year and remain together for the next two semesters as they collaboratively develop a polished product using CakePHP. Each group is assigned a customer who represents a char- itable organization in the community that has a software development need to be filled. Before the start of the first semester, the customer provides a brief request

including in- formation about the organization, an overview of the desired system, and three feature lists: minimum, desired, and op- tional requirements. The teams are also assigned a mentor

with the necessary technical skills and expertise to help aid them throughout the development process.

The deliverables of the in-class projects present the non- profits with functional pieces of software that would have been much more costly to purchase or develop internally. It also a↵ords the development team professional experience in creating software systems. Both of these goals coincide with the mission statement of the Humanitarian Free and Open Source Software Project to provide humanitarian organiza- tions free software solutions created by individuals with the necessary technical knowledge [6].

2. BACKGROUND

The creation of a micro-endowment donation platform re- quires integrating a myriad of di↵erent pieces, such as exter- nal payment systems, Internal Revenue Service (IRS) forms, and investment accounts. Not only do donors and charities both need to register with the system, donors also need to supply payment methods in order to e↵ectively use the ap- plication. Furthermore, charities need to be authenticated to ensure that they are federally recognized charitable non- profit organizations. Also, in order to comply with federal tax policy, giv2giv must review all donations before money is actually delivered to the receiving charities. During this review process, giv2giv holds the donors' money in invest- ment accounts. As a result, these funds are subject to ap- preciation and depreciation, changing the total value of the fund. Developing a solution to giv2giv's problem statement that adheres to all of these constraints requires understand- ing and addressing some of the intricacies of the nonprofit donation space.

Each charity has an employee identification number (EIN) assigned by the IRS that is used to authenticate a charity at sign-up. Giv2Giv receives a list of federally recognized charitable organizations from the IRS that contains all of the registered EINs. In order to begin receiving donations, the charity account must also supply a 501(c)(3) form. This form is then stored by giv2giv for tax purposes. This multi- step authentication process ensures that giv2giv is only giv- ing donations to federally recognized charitable nonprofit organizations.

Another important piece of information about giv2giv's pro- tocol is the frequency of donations. The organization re- quests micro-donation contributions from their donors on a monthly basis.

However, it only actually transfers a portion of the money to the receiving charities every three months. Thus, during the period in between transfers, donors' money is stored in an investment fund where it is subject to appre- ciation and depreciation. The rationale behind this is that small, monthly contributions will grow and accumulate in- terest over time. This means that donors are actually giving a larger contribution than their original donations, which helps them provide a greater positive impact upon their fa- vorite charities.

3. RELATED WORK

Although there are other charity-focused sites on the web, none of them address charitable giving in the exact way that giv2giv does. Similar systems include GuideStar, Causes, and Razoo. Although all three of these systems are online

sites that focus on user interaction with charities, giv2giv di↵erentiates itself through its unique use of charity packages and investment funds.

One of the most well-known charity-focused sites is GuideStar. GuideStar provides a comprehensive guide to all IRS-registered nonprofit organizations [5]. Its goal is to be a single source of information regarding individual charities. However, this site does not provide a direct way to donate to these char- ities. In contrast, giv2giv's primary goal is to allow donors to find and contribute recurring donations to their favorite nonprofits. Therefore, it is necessary to supply, within the giv2giv application, the information required to make that financial decision and provide a medium to enable the nec- essary transactions.

Causes is an online Facebook application that shares many similarities with giv2giv. Like giv2giv, Causes takes a crowd- sourced approach to spurring community involvement and donations towards di↵erent causes or issues [3]. Also simi- lar to giv2giv, the application uses Facebook social integra- tion to spread awareness about potential charitable causes. However, the major di↵erence between the two applications is that Causes allows anybody to receive funding for any type of issue [4]. This can include non-charitable events such as boycotts, petitions, and more. Users of Causes also do not need to donate money; they can provide other ac- tivities such as volunteering or sending goods. Giv2Giv, on the other hand, only allows monetary donations to authenti- cated, federally registered charities. This is a key distinction between the two companies and helps giv2giv focus on a dif- ferent target market and user base than Causes.

Razoo is an online donation system that is the most similar to giv2giv. Both Razoo and giv2giv

focus on allowing users to create recurring donations to charities of their choice [8]. Also, both systems put an emphasis on using social network- ing tools to spur interest in charitable donations. However, there are a few major di↵erences between the two organiza- tions. The first major di↵erence is the frequency of donation to the charities. Razoo takes a user's donation and stores it in a fund for only a single month before transferring it to the charities. This means that they do not focus on generating compounding interest on a user's initial donation. Giv2Giv keeps the donations in its investment fund for a longer period of time in order to accrue interest for the charity in the long term. A second di↵erence is that Razoo deals primarily with donations to specific causes for a single charity. For example, users are able to donate money to Habitat for Humanity, but they can specify that they would like their donation to be reserved for the building of a specific house and not for gen- eral use by the charity. Giv2Giv, on the other hand, creates packages that focus on a higher-level cause, such as home- lessness, by organizing a handful of charities together in a single package. These funds can also be used by the receiv- ing charity in any manner that they need. Lastly, Razoo is not a system that can be purchased for use. Giv2Giv could not have used Razoo to achieve its goals because it could not have purchased Razoo's system as an o↵-the-shelf product. Thus, giv2giv was forced to architect its own system.

Because there is no o↵-the-shelf product that fills giv2giv's specific need, we built the giv2giv web application from the

ground up.

4. SYSTEM DESIGN

Donors register with giv2giv online and then are able to do- nate to certain charities that have been grouped together in packages. Giv2Giv requests the donation on a monthly ba- sis from the donor's funding source of choice. The donations are transferred into giv2giv's own Dwolla account where they are then invested with TD Ameritrade[1]. The donations ac- crue interest within the investment fund over time. Once a quarter, a small percentage of the invested funds are re- moved and distributed to the charities in accordance with the initial donor's specifications. In order for these charities to receive their donations, they must also have an account with giv2giv and have verified their status as a legitimate charity. A graphical overview of the main funds entities in the giv2giv system and the monetary interaction frequencies between them can be seen in Figure 1.

In order to track the contributions of each user into the in- vestment fund, a system of stakeholders and shares was cre- ated. As the value of the fund changes, the value of the share

price fluctuates accordingly. When a user makes a monthly donation, he ‘purchases’ more shares in an investment fund.

4.1 Packages

Instead of requiring donors to specifically select each charity they wish to donate to, groups of charities are organized into packages as defined by the creator, e.g. impacting home- lessness in Charlottesville, VA. Packages provide a preset grouping of information to allow for easier donation. This also allows groups of donors to unite behind a cause and to raise awareness for that cause. Each package has a minimum donation amount, a specified investment fund or funds for the donations, and a percentage distribution of the dona- tions for each charity in the package.

4.1.1 Creation

Any user of the system is allowed to create any number of packages. The package creator can choose the name, mini- mum donation amount, investment fund or funds, member charities, and percent distribution to those charities. Others

[1] https://www.tdameritrade.com/

who donate to this package can contribute more, but not less than, the specified minimum donation amount. Di↵erent in- vestment funds are available varying by the desired return rate and amount of risk associated with each investment. If multiple funds are selected for a package, the donations into that package are split evenly between the investment funds. There is no minimum or maximum number of charities that must be in a package. This allows users to tailor packages to be as generic or specific as they wish. A package can also be specified as private, so that others cannot search for, view, or donate to that package; it exists solely for the package creator.

4.1.2 Subscription

Upon subscribing to a package, the user pledges to donate at least the minimum donation amount each month until they unsubscribe. When users subscribe to a package, giv2giv creates a recurring donation from the user’s funding source to giv2giv’s Dwolla account. Once anyone subscribes to a package, the owner loses his ability to edit that package. This decision was made to ensure that that the package owner has no control over other donors’ money that the donor is unaware of. Package creators do not hold steward- ship status, they merely serve as curators of good package ideas for the system. If someone would like to tweak the settings of a package they may clone it and then make edits.

4.1.3 Cloning/Duplication

Package duplication makes it quick and easy to take an ex- isting package and add your own tweaks. To duplicate a package, a user can simply click the ‘Clone This Package’ button. The included charities, the percentage distribution of donations to these charities, and the minimum buy-in amount are copied over to a new package named, ‘[Name of Original Package] Clone’. Since this user is the creator of this new package, he can proceed to edit it to his liking.

4.1.4 Searching

Both individual charities, and packages can be searched to allow users to find the best match. Charity lookup searches over charity names, mission statements, and addresses. Pack- age lookup searches over package names and any associated tags. Any user of the web application can tag a charity or package. This crowd-sourcing technique allows users to as-

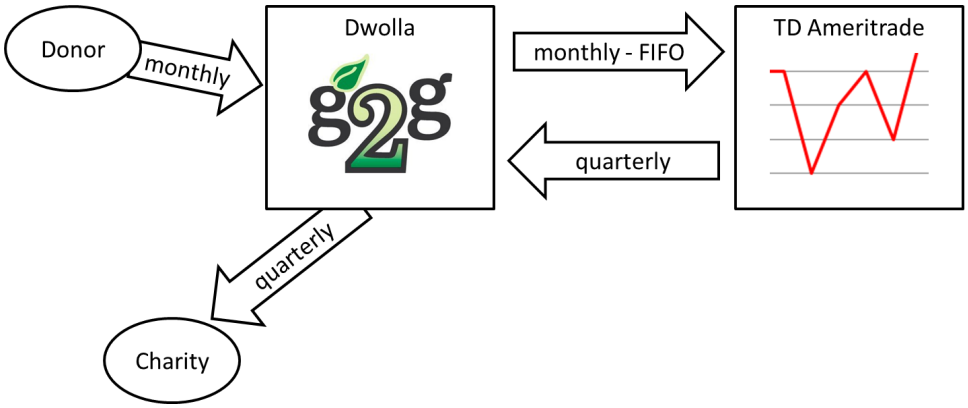

Figure 1: Monetary interaction frequencies between the primary giv2giv entities

sociate additional data with a charity or package. Each tag can also be voted up or down in a semblance of a report- ing mechanism. Each package inherits its member charities’ tags to reduce manual duplication. Currently, there is no support for ranking the search results based on relevance.

4.2 Login and Authentication

In order to do anything beyond searching charities and pack- ages, users must be registered with the giv2giv application. For donors, a two-step login workflow was created. Users first register with the system by supplying their email and password. An email with a link is sent to that address to verify that they own it. Due to the nature of the system, giv2giv must have a way of communicating with the donors.

Charity registration is more complicated. They first request an account by providing the EIN of their charity, an email address, and their name. Giv2Giv then verifies with the charity, often over the phone, that that employee is autho- rized to speak on behalf of the charity. If so, giv2giv ap-

proves the request in the system. This creates a new charity user account and notifies the charity of their request's ap- proval at the email address originally given, providing them with a password for their new account.

Each donor is required to register a funding source when they create an account on the website. These funding sources include Dwolla and PayPal. If a donor does not have an account for either, he is directed to create one before con- tinuing. If a user fails to input or create a funding source, he will not be registered with giv2giv.

4.3 Funds Tracking

The giv2giv financial model has donations coming into giv2giv's bank account from a donor's Dwolla account, going out into one or many investment funds to accrue interest, coming back into giv2giv's bank account, and finally going out to charities for donation. In order for this process to flow smoothly, a robust funds tracking system is required. Giv2Giv must know at any point in time the location of all its money,

as well as which donor "owns" that money (i.e. that money is attributed to them and will eventually be donated to the charities of their choice).

Since each investment fund will inevitably change in value due to appreciation or depreciation over time, the tracking system was implemented with a concept of "shares". Each donor buys and sells shares of an investment fund at the current market price. For example, let's say Bob donates ten dollars to giv2giv this month. When that ten dollars is transferred into an investment fund, Bob will receive as many shares as that ten dollars will buy him at the current market price. In a month, that market price will likely be slightly higher than it is today, meaning the value of Bob's shares will have gone up. Each quarter, when donations are withdrawn from the investment funds to be donated to charities, some fraction of John's shares will be 'sold', or liq- uidated. Thus, the current market value of the 'sold' shares will be withdrawn from the fund and donated to charities, and Bob's total count of shares in the fund will go down by the amount of shares that were sold.

Altogether, this system tracks the total value of giv2giv's

funds as well as what fraction of these funds are attributed to each user at all points in time.

4.3.1 Webhook Notifications

The giv2giv web application uses Dwolla as the payment service to transfer funds throughout the

system. On signup, donors must choose either Dwolla or PayPal as a funding source to link to their giv2giv accounts. Although linking both services is supported, we have only implemented the full Dwolla payment workflow in our application. This is a design decision made by the development team and the customer because the giv2giv organization only currently uses a Dwolla account to receive donations. PayPal is a part of the plan for future work on the system.

Dwolla webhooks notifications are crucial to the funds track- ing portion of the giv2giv application. From a user stand- point, it allows donors to see exactly how their investments are being utilized and how their donations over time will benefit their favorite charities. Operationally, webhooks en- able giv2giv to maintain accurate records of all money trans- actions taking place in the system. This is important for both error checking and tax purposes.

There are two main types of activities used in the interaction between the giv2giv application and Dwolla: requests and transactions. Requests are created when giv2giv asks donors for their monthly donations; they are fulfilled whenever the donor manually accepts the money request. Transactions are created whenever money physically transfers between accounts. Dwolla creates webhook notifications whenever a money request is fulfilled, a transaction is created, or the status of a transaction changes. Our application is set up to receive these webhook notifications and handle them ac- cordingly.

The webhooks notification workflow happens behind the scenes of the application. There are no views associated with the handling of the messages, but system administrators can view all of the requests and transactions after they have been recorded from the administrator dashboard.

4.4 Social Networking Components

An important part of this web application is to raise aware- ness about the services giv2giv provides and increase the visibility of the website in order to generate more charita- ble donations to nonprofit organizations. To address this goal, we added social networking components that utilize the following sites: Facebook, Twitter, and Google+. In addition to increasing the visibility of giv2giv, we harness the demographics of giv2giv users from the associated social networking sites.

To link giv2giv accounts to social networking sites, we use Open Authorization (OAuth), an open standard for web au- thorization. OAuth allows users to give 3rd-party applica- tions access to their private resources, such as Twitter time- lines or Facebook posts, without giving them passwords or other account credentials [7]. If the 3rd-party application gets hacked, it is possible to simply revoke access to that app. The application does not store login credentials, so it is a secure method that does not allow hackers access to a user's login information. Some sites make

users login to

their social media accounts in order to post or tweet on the user's profile. When using OAuth applications, it is impor- tant to note what permissions are being requested by the application.

4.4.1 Facebook

The Facebook component of the system is designed to give users the ability to share their donation stories with their friends on Facebook. For this to work properly, users need to have a method of connecting their Facebook accounts to the giv2giv website. This is accomplished by creating a giv2giv application on the Facebook Developers website that is used to recognize whether a user has approved giv2giv to interact with their Facebook account.

This component of the system is designed to give users a number of options for how tightly they want to link their Facebook account with the giv2giv web application. The first, and most basic, level is the presence of a 'like' button on the giv2giv website that allows users to like the giv2giv Facebook page. Using this link, users can also write a short message to their Facebook friends that contains both a short blurb on the giv2giv idea and their own custom message. This link also includes basic features for seeing social net- working relationships. Even if the user has not connected his Facebook account yet, he is still able to see which of his friends have also liked the giv2giv page on Facebook.

The second level of Facebook connectivity gives users the ability to semi-permanently connect their Facebook accounts to the giv2giv page. This is accomplished through the pre- viously mentioned giv2giv application. When connecting their Facebook accounts, users are given a number of op- tions for which permissions they would like to share with the application, and therefore, with the giv2giv website. Users are asked to give, at minimum, the basic information that Facebook requests when using its application, including id, name, gender, and more. Depending on whether users want to activate certain features of the giv2giv web application, they are also asked to share permissions for additional in- formation that allows the application to publish stories to their Timelines. If users give the application this share per- mission, they are able to automatically share instances of when they donate money to a package on their Facebook Timelines. Alternatively, users are also able to share the story manually with the click of a button. If users do not give the application share permission, their use of the web- site is not significantly a↵ected. The only change is a lack of functionality for sharing stories to their Facebook Time- lines. This decision allows users the option of integrating their giv2giv actions with Facebook without explicitly forc- ing that integration in order to use the website. Users can also grant a limited number of permissions to the giv2giv Facebook application. If they choose to only grant permis- sions for the basic information, that information is stored into the giv2giv

database and can be used to give users a customized experience. Again, if the user chooses not to share this information, his overall giv2giv experience is not hindered.

4.4.2 Twitter

Similar to Facebook, the Twitter interface is designed to allow each donor the ability to link a Twitter account to his

giv2giv account using OAuth. This allows the user to set up automatic tweeting upon a donation or package creation. The user can also craft customized tweets about giv2giv.

When a user requests to link a Twitter account, the applica- tion directs the user to an authorization page that asks the user to grant the giv2giv application permission to read and post tweets and messages, as well as look at information about the user and their followers. Changing the OAuth request token can modify these permissions. If the user chooses to not grant these permissions, their use of the web- site is not significantly a↵ected.

If the users do grant the requested permissions, they are redirected to the giv2giv website and an OAuth access to- ken containing both an ID and key is stored in the database to enable tweeting. Once the user decides to tweet about a giv2giv event, the interface handles this and stores the user's Twitter ID. This ID can be used in the future for demographic purposes, such as enabling the use case of sug- gesting the giv2giv website to a user who is following the Twitter accounts of other giv2giv donors. Automatic tweet- ing can be toggled on or o↵ on the user's account manage- ment page and the user can revoke Twitter access at any time. This decision was made to respect the users' privacy.

4.4.3 Google+

We designed the Google+ interface to be very similar to that of Facebook and Twitter. The goal is to link a user's Google+ page to giv2giv. Currently, Google+ is setup to re- quest basic information and request information about the people in the user's circles. We can eventually expand this scope for more demographic information and perhaps post messages on the user's behalf (similar to auto-tweeting). Similar to Facebook and Twitter, we store the demographics information in the database to give the user a personalized experience based on the people in their circles. Also, users can, at any time, revoke access through their application settings page.

5. PROCEDURE

The giv2giv web application has use cases for three di↵erent stakeholder groups: donors, charities, and administrators.

Donors who want to donate through giv2giv must register an account through the website. With this account, donors can create or donate to packages using either Dwolla or PayPal as their chosen payment method. Packages define a common cause for donation and contain a user-defined list of chari- ties. Contributions to a package are distributed among the charities in that package.

Any donor has the ability to create packages. To create a package, a donor must define the minimum monthly dona- tion amount, an investment fund for the donations to be held in, the charities the package will support, and the per- centage of the monthly donation reserved for each charity. A package can be set as private or public. Public packages are visible to all users, while private packages are only vis- ible to the creator. Once any donor signs up to contribute to a package, its owner can no longer edit that package.

Donors are able to search and view all public packages in

the giv2giv system. If they find a package they like, they can sign up to begin donating to that package. Donors may choose the amount of their monthly donation, but that amount must be greater than or equal to the minimum do- nation amount of the package. Giv2Giv also uses social net- working to allow donors to share their donations or packages via Twitter, Facebook, or Google+.

In addition to donors, charities can also register for an ac- count to begin utilizing giv2giv's services. Charities must first request an account on the website, and giv2giv follows a sequence of steps to verify they are indeed a federally rec- ognized nonprofit organization. Although charities without giv2giv accounts are still viewable on the system, signing up for a giv2giv account o↵ers charities the added benefits of creating a customized profile page, defining their own mis- sion statement, and receiving donations. Charities can also tag themselves with certain keywords to increase their visi- bility in search results.

Finally, the customer has an administrator account with spe- cial privileges. The customer can keep track of all transac- tions made in the system. These transactions include who sends money where, which accounts are receiving money, and the monetary amount in each transaction. Every month, the customer can request the money that donors have agreed to donate from their Dwolla or PayPal accounts by clicking a button on his administrator dashboard. The customer can thus move the money from the donors' account into the appropriate investment funds or withdraw money from the investment funds and transfer it to the charities. This ad- ministrator account allows the customer to manage giv2giv's overall system from a centralized location.

6. RESULTS

The giv2giv application currently maintains records for all 828,156 charities recognized by the IRS. Each charity or package can be tagged with any of 72 di↵erent tags. The sys- tem can easily handle the addition of tags as they become necessary. It was built with a user space of 300, 000, 000 in mind, but is not limited to that number. The applica- tion listens for and records 12 monthly transactions for each package that each user is subscribed to. Also, an unlimited number of packages can be created, and a user can subscribe to an unlimited number of packages. All of these numbers suggest that giv2giv should be able to scale well as more users begin registering for the system.

7. CONCLUSIONS

Our development team began with a blank CakePHP frame- work and now has successfully implemented a fully func- tional micro-endowment web application. Although there is certainly room for improvement, the system is working and can be used as a great starting point for giv2giv to build upon for the future. Users can register online for giv2giv and select their preferred payment method. They can cre- ate, donate, and track their donations to various packages and subsequent charities. Charities can register with giv2giv and edit their account information to enable greater search visibility. Donors can share their contributions on a vari- ety of social networking sites. Transactions between Dwolla accounts can be tracked automatically via webhooks and stored in the database, which allows for transparency and

tax recording. With development of the application com- plete, all minimum and desired requirements set forth in the customer's initial requirements document have been met. Overall, this system is successful in enabling a true micro- donations charitable contributions platform that leverages open source software. This project also a↵orded the devel- opment team a year of hands-on experience in a customer- driven production environment.

8. FUTURE WORK

This project has a host of future work ahead of it. The most desirable addition would be a fully developed UI/UX framework to unify the site into a visually pleasing, cohe- sive, and easy-to-use system. The existing user interface is simply the default framework provided by CakePHP with minimal tweaks. A complete UI overhaul will create a sys- tem that better engages the user and improves the overall user experience.

Several administrative aspects of the system require manual participation. These actions include

updating the charity information, updating fund values from the investment fund, and requesting monthly transactions. In the future, as the functionality becomes possible, these features should become automatic.

Searching over charities and packages is currently primitive. A better searching algorithm should be created. This could include ranking the results based on number of subscribers to each, positive up-votes for matching tags, or by date cre- ated.

Currently, the only fully supported payment system is Dwolla. Users can link their PayPal accounts. However, they cannot actually make donations using a PayPal account. Due to the popularity of PayPal, we would like to completely integrate it with the system in order to o↵er the user more payment options. PayPal was not initially implemented due to the amount of time required to integrate with external systems and because the customer prioritized Dwolla over PayPal.

Although this is a donor-advised, rather than a donor-managed fund, we would like to provide greater transparency to the user at every step of the process. This can include phys- ically notifying the user when money has been transferred from giv2giv's Dwolla account to the investment fund, when his contributions appreciate or depreciate, and the when quarterly withdrawal and distribution out to the specified charities occurs.

The giv2giv system is expected to persist over an extended period of time. This focus on longevity creates certain bound- ary cases that need to be considered. Important questions include: What happens when a charity becomes inactive? Does the allotted money for that charity become redistributed to the other charities in the package? How do we handle a user choosing to delete his account? For reporting purposes, that information can never be deleted, however, it can be hidden from any future logins. This implies that the email associated with the account can never be reused for another account. A significant piece of the future work needs to focus on correctly and consistently handling all of these potential situations.

As other similar organizations o↵er, we believe giv2giv could be expanded to allow donors to contribute to specific causes within a charity, and not just the general organization. This would require additional functionalities within the system to handle these causes, as well as an expansion of the charity- user role to allow individual charities to create causes within the system.

The social networking components are an integral part of spreading grassroots awareness of di↵erent packages, chari- ties, and potential causes. These can be expanded to show the user how

many of his friends are donating to giv2giv, how much his social network has contributed to a certain package or cause, or even how much people in his geographic area have contributed. These enhancements can be designed to educate the user about the power of crowdsourcing and encourage him to tell others.

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Social Entrepreneurship Priorities in the Hardware, Software, and Computing Systems Industry: A Case Study on Elon Musk

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By

Douglas Milvaney

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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.

Signed: _____ Date: _____

Approved: _____ Date: _____

Social entrepreneurs in the technology industry are constantly searching for novel ways to structure and utilize their technical skills in order to solve pressing social issues (Dees, 1998). Although the practice of social entrepreneurship has been around for some time, only in the past decade has it become a popular topic for scholars (Dees, 1998; Noruzi & Rahimi, 2010). Noruzi and Rahimi (2010) define social entrepreneurship as "responding to market failures with transformative and financially sustainable innovations aimed at solving social problems" (p. 760). A lack of empirical studies in this space has left social entrepreneurship research in an "embryonic state" (Short, Moss, & Lumpkin, 2009, p. 161). This STS research paper presents a case study on the entrepreneur Elon Musk that uncovers what social entrepreneurship practices are present in the modern-day hardware, software, and computing systems industry. The answers to this question shed light on how entrepreneurs are attempting to solve mankind's most challenging problems and add tangible discoveries to this nascent space.

Why Elon Musk?

Elon Musk is a prime example of an individual currently crafting solutions to some of the world's most pressing social problems. Musk is the Chief Executive Officer and Chief Technology Office of Space Exploration Technologies Corporation (SpaceX), a company that is pioneering low-cost spacecraft (Studt, 2007). He is also the chairman of three other entities, including Tesla Motors, whose mission is to provide low-cost, low-emission electric vehicles for everyday use, and SolarCity, a company focusing on enabling households to harness clean, sustainable energy (Studt, 2007). All three of these ventures are addressing timely social issues, particularly those concerning sustainability. Hockerts and Wüstenhagen (2010) describe a

growing trend of entrepreneurs disrupting stagnant markets in order to increase sustainability and decrease environmental impact. This description embodies the ideals behind Musk's endeavors. Since he is a social entrepreneur who oversees multiple corporations, Elon Musk provides multiple data sources to analyze. Furthermore, Elon Musk has structured his primary businesses to solve social issues. This differentiates him from other entrepreneurs and makes him a good fit for a social entrepreneurship case study.

This paper discusses SpaceX, Tesla Motors, and SolarCity, and presents details about the important motivations and aspects of each venture. It examines Elon Musk's personal values to determine which may have contributed to his success. This paper also presents an analysis of the research's findings and compares them with the published literature about social entrepreneurship to see if the factors contributing to Elon Musk's successes are representative of the hardware, software, and computing systems industry as a whole. Although it is possible that Elon Musk is a unique example, this study can still shed light on which social issues are being addressed, describe how some ventures are attempting to address these issues, and serve as a framework for budding social entrepreneurs to construct their ventures upon. By basing the study on projects with similar aspirations and subject areas, comparing his ventures' success to his own expectations, and drawing on Musk's personal values and experiences, this research identifies the factors that have lead to Elon Musk's current successes. My thesis is that Musk has focused his ventures' goals on solving environmental sustainability issues and is structuring his resources and knowledge to create novel and financially successful solutions to these major social issues.

Elon Musk's Ventures

All three of Elon Musk's companies focus on addressing sustainability issues by creating low-cost technologies that can be reused (Studt, 2007). This paper uses this overarching goal as a point of comparison with other sustainability-focused projects. In their dual case study, Horwitch and Mulloth (2010) examine various aspects of two clean technology corporations. Major focuses of their study include the corporations' technologies, project management approaches, and motivations (paraphrasing Horwitch & Mulloth, 2010, following "Abstract"). Analyzing these factors serves as a great starting point for the examination of Elon Musk's ventures and helps identify the elements contributing to his success.

Space Explorations Technologies Corporation

Elon Musk founded Space Exploration Technologies Corporation in 2002 to address a "sustainable energy economy and space exploration," two of the biggest social issues Musk believes mankind is currently facing (Canan, 2009, p.1). Although Musk's primary motivation for SpaceX is to enable colonization of other planets, the venture has evolved to take on the complementary goal of making a reusable rocket system at a fraction of the cost of those currently available (Anderson, 2012; Canan, 2009). Two of SpaceX's major systems working towards this goal are the Falcon 9 rocket and the Dragon reusable spacecraft. The Falcon 9 rocket is an Evolved Expendable Launch Vehicle used to help launch different payloads into orbit, while the Dragon capsule is able to orbit the Earth and carry cargo into space (Canan, 2009; "SpaceX," 2013). In 2008, the National Aeronautics and Space Administration (NASA) contracted SpaceX to use these two systems to bring supplies to the International Space Station

through multiple trips between 2010 and 2015 (Anderson, 2012; Canan, 2009; “SpaceX,” 2013). In May 2012 as part of this contract, the “Dragon spacecraft became the first commercial vehicle in history to successfully attach to the International Space Station” (“SpaceX,” 2013, following "Dragon Overview"). In December 2012, SpaceX received a two-flight contract from the United States Air Force for its Falcon rockets (Ingraham, 2012). For a company just over a decade old, these contracts and launches have been outstanding successes that can be attributed to SpaceX’s development of advanced technologies, fostering a creative and exciting work environment, and being motivated to create reusable rocket systems at an economically feasible level.

Advancing the current state of spacecraft technologies is a key component of SpaceX’s mission to create a fully reusable system. In a 2012 interview, Elon Musk stated that the primary way to evaluate technology advances is by cost (Anderson, 2012). Thus, SpaceX focuses on sourcing cheaper materials and developing new frame architectures and production mechanisms to enable the systems to be lighter, require fewer resources, and ultimately reduce the total cost. Furthermore, the company takes a different approach from other major spacecraft manufacturers and vertically integrates its production to reduce overhead costs and price markups that result from purchasing materials and parts from other suppliers (Anderson, 2012; Canan, 2009; Dreyer, 2009; “SpaceX,” 2013; Studt, 2007). SpaceX has been able to develop unique production processes for the frame of a rocket that eliminate much of the wasted material found in other more outdated techniques. This process is accomplished by using “ribs and hoops” that provide the necessary stiffness but with less material (paraphrased from Anderson, 2012). The company also utilizes a proprietary welding technique called “stir

welding" that improves the strength of rivets and minimizes materials lost in the process (Anderson, 2012; "SpaceX," 2013). This approach of internally developing new technologies and using them to manufacture its spacecraft has enabled SpaceX to produce rocket systems at a lower cost than its competitors. This reduction in cost structure has translated into real-world success, making SpaceX an attractive company for space exploration contracts.

Another way SpaceX is advancing spacecraft technologies is by fundamentally rethinking what it means for a rocket to be reusable. Although portions of the NASA space shuttle were able to be recovered, subsequent flights would still cost more than purchasing a new expendable rocket, effectively eliminating the cost benefits of the reusable portions (paraphrasing Musk, 2009, p. 41). With this knowledge, SpaceX set out for the Falcon rockets to have a fully recoverable first stage. As of the writing of this paper, the Falcon launch vehicle's first-stage rockets are jettisoned into the ocean to be retrieved, similar to that of the space shuttle (Paur, 2013). However, SpaceX is currently working towards integrating rockets that can provide fully autonomous vertical landings (Anderson, 2012; Paur, 2013). In March 2013, the SpaceX Grasshopper project completed its most successful test launch in which the rocket autonomously took off, hovered, and then landed vertically. The company eventually plans to integrate this autonomous landing system into its rockets to create a fully reusable and recoverable launch vehicle (Paur, 2013). These technological advancements and ambitious goals to create fully reusable rocket systems bode well for SpaceX's success in the commercial rocket launch market.

From a managerial standpoint, SpaceX's conscientious effort to promote creativity, problem solving, and risk-taking may also contribute to its success. Elon Musk believes that

confining his employees to a standard protocol or procedure stifles creativity (Anderson, 2012). He would much rather hire bright individuals and let them solve problems with novel thinking. Musk's desire to take risks and never accept failure is another characteristic that he wants to incorporate into SpaceX. Musk (2009) explains that despite the three initial launches not reaching orbit, the team never gave up and used its experiences to iteratively design and improve the rockets (p. 41). As CEO of SpaceX, Musk takes a very hands-off management approach. He delegates most of the managerial duties to other individuals in the corporation, and instead focuses on technical work (Studt, 2007). Musk has been able to foster these characteristics in the nature of SpaceX in order to help enable his employees to succeed.

SpaceX's primary motivation of expanding human space exploration focuses on an indirect strategy for addressing sustainability issues. Potential uses for colonization of other planets may include harvesting resources and mitigating the effects of overpopulation. The success SpaceX has achieved and the contracts it has garnered shows that there is support behind these endeavors. However, Musk is also attempting to create solutions to directly reduce mankind's impact on the environment here on Earth through Tesla Motors and SolarCity.

Tesla Motors

In 2004, Elon Musk co-founded Tesla Motors as another part of his quest to create a "sustainable energy economy" ("Tesla Motors," 2013, following "Executives"). Musk (2006) believes that both solar and electric power are key factors in mankind's pursuit of true sustainability. Tesla Motors addresses the electric portion of this belief by developing all-

electric vehicles that consumers will actually want to buy. Paul Lomangino, an Engineering Tools Manager at Tesla, describes some of the functional and non-functional requirements for their vehicles to include being “attractive, fun to drive with great range, and fantastic performance” (Hearne, 2012). Similar to his goal with SpaceX, Musk wants to disrupt an established industry by increasing sustainability, lowering costs, and advancing the current state of available automotive technologies.

As with most of Musk’s endeavors, sustainability and CO_2 reduction are at the heart of Tesla Motors. Rather than compromising and creating hybrid vehicles, all Tesla models are fully electric because the company wants to fundamentally change the public’s perception about what an electric vehicle can be. As Musk puts it, hybrids are only “slightly more efficient gasoline powered cars” (Elon Musk, 2006, after "Power Plant Emissions aka 'The Long Tailpipe'"). Hybrids do not fit into Musk’s vision because he is committed to reducing the automotive industry’s reliance on gasoline. As seen in Figure 1, the electric Tesla Roadster has the lowest CO_2 emissions levels of the types of engines Musk performed calculations for. Specifically, the Roadster emits 65 percent less CO_2 than the Toyota Prius, a hybrid vehicle. Producing vehicles with statistics like highest efficiency and lowest CO_2 emissions is one of the steps Tesla Motors is taking to foster public excitement about an electric car.

Car	Energy Source	CO_2 Content	Efficiency	CO_2 Emissions
Honda CNG	Natural Gas	14.4 g/MJ	0.32 km/MJ	45.0 g/km
Honda FCX	Nat Gas-Fuel Cell	14.4 g/MJ	0.35 km/MJ	41.1 g/km
Toyota Prius	Oil	19.9 g/MJ	0.56 km/MJ	35.8 g/km
Tesla Roadster	Nat Gas-Electric	14.4 g/MJ	1.14 km/MJ	12.6 g/km

Figure 1: Comparison of CO_2 emissions between different engine types (Elon Musk, 2006)

A supplementary step in making Tesla models sustainable involves building a network of electric charging stations across the country. If electric car owners do not feel comfortable driving their cars for long periods of time for fear of running out of charge, the vehicles will not be adopted at a level necessary to achieve true change in the automotive industry. Although Tesla models can be charged at standard electric charging stations, Tesla is currently attempting to accelerate this process by building its own supercharging stations across the United States. These stations offer a fifty percent battery charge in thirty minutes (“Tesla Motors,” 2013). As of the writing of this paper, Tesla has already built nine of these stations, and plans to expand this number to over one hundred by 2015 (paraphrasing “Tesla Motors,” 2013, following "Supercharger").

Another similarity Tesla has with SpaceX is the goal of producing low-cost products. However, with the high cost of the new technologies being utilized, the company must strike a balance between offering low prices for the vehicles and making a profit. In 2006, Musk stated the company’s long term plan was to iteratively design different vehicle models that drop in

price in accordance with the technologies gaining economies of scale (Musk, 2006). When asked if Tesla plans on making a mass-market car, he elaborates that Tesla is following a three-step plan of sequentially offering an "expensive car at low volume," followed by a "medium price, medium volume" vehicle, and culminating in a "low price, high volume" produced car (Musk, 2013). The first model, the Tesla Roadster, was an expensive sports car that was primarily used as a proof of concept that electric vehicles could perform as well as or better than gasoline-powered cars. The car had a high price point, but the revenue generated from its sales was invested back into the company to help aid in developing lower cost models and reducing the price of the technologies used (Musk, 2006). In addition to the Roadster, Tesla now also offers the Model S four-door sedan that is priced around $50,000 and has plans to release a $30,000 car around 2016 (Musk, 2013). This commitment to lowering the prices of its vehicles proves that Tesla is serious about changing the automotive market.

Evaluating the success of Tesla Motors requires analyzing more than just the economics of the company. Although founded in 2004, Tesla Motors hopes to achieve profitability for the first time in the first quarter of 2013 (Voelcker, 2013). This lack of profit generation may seem like a warning sign for an unsuccessful corporation, but when evaluating the results against the company's stated goal of reducing mankind's dependence on non-renewable energy sources Tesla is on the right track. For example, with production not quite at full scale, Tesla has implemented a reservation system for its cars. At the end of 2012, the company had a waiting list of over 15,000 people (Voelcker, 2013). This waiting list shows that there is a demand for all-electric cars, and once Tesla is able to begin ramping up production and continue lowering costs, its profits will likely increase as well. Thus, from a profitability standpoint, Tesla has not

yet achieved its major aspirations. However, as a young company working on advancing technology and changing an entrenched industry, Tesla Motors has set itself up to be the likely leader in the electric vehicle market and a legitimate competitor to other automotive manufacturers regardless of fuel type.

SolarCity

SolarCity is a corporation addressing the social issue of sustainability by attempting to make solar panels a more attractive option and a cheaper method of harnessing energy for consumers. The ultimate goals of the corporation, and of solar panels in general, are to reduce reliance on the electric grid, lower energy costs for homeowners, and help reduce humanity's overall carbon footprint (Mims, 2009). However, the major issue facing the solar panel market is not the lack of suitable technologies but the high cost and difficulty of installing solar panels (Mims, 2009; Studt, 2007). In order to combat these issues and quickly get solar panels onto the roofs of homeowners, SolarCity is attempting to change the cost structure and public stigma surrounding solar panels by providing free installation, partnering with large companies, and expanding to states that provide tax incentives to homeowners using solar power.

The major component of changing the cost structure of solar panels lies in combatting the high price of the installation process. SolarCity takes the approach of eliminating the startup cost of solar power. They have achieved this by providing all design, installation, and maintenance of the panels for free; the only cost to the homeowner is the monthly electricity bill (Lashinsky, 2013; "SolarCity," 2013). This alleviates difficulties for the homeowner and enables faster startup time to begin harnessing solar power.

SolarCity also partners with large corporations such as Home Depot and Honda in order to get its solar panels into the hands of consumers. Home Depot is providing in-store consultations to consumers on the benefits of harnessing solar power, and how to begin using SolarCity's offerings (Lashinsky, 2013). Honda is using its partnership with SolarCity to decrease their resource usage and inform their customers about clean energy choices (paraphrasing Lashinsky, 2013). Pacific Gas and Electric Company is another company that is on-board with SolarCity's mission to reduce reliance on the electric grid. The company has provided advertisements for SolarCity as another means to educate the public on their options for receiving power (Studt, 2007).

SolarCity has seen economic success resulting from its cost structure and partnerships. In 2007, the company held the largest market share of solar panel installers in the United States (paraphrasing Studt, 2007, p. 22). According to Mims (2009), SolarCity still retained this lead in 2009. Perhaps most telling, however, is that its December 2012 initial public offering share price of eight dollars had increased to nineteen dollars by February 2013 (Lashinsky, 2013). This increase may be a result of the growing acceptance of solar power as a feasible form of energy; Goossens (2013) explains that the number of installations of solar panels in the United States increased 76 percent in 2012. These statistics suggest that SolarCity is in a position to take advantage of the growing solar market and continue to use its business model to help homeowners reduce electricity bills and their carbon footprints.

Comparison of the Ventures

Although SpaceX, Tesla Motors, and SolarCity focus on sustainability and lowering costs in their respective industries, each has achieved success by following very different paths. These differences include the importance of new technologies to each venture and the role played by Elon Musk. SpaceX and Tesla both focus on creating cutting-edge technologies. Doing so enables both ventures to reduce the costs associated with development of their systems, and helps differentiate each from their competitors. In contrast, the market for photovoltaic cells does not see much differentiation in technologies (Studt, 2007). However, SolarCity was able to separate itself from the other contenders by offering free solar panel installation. Thus, the three companies achieved success in their respective industries by taking different approaches in business strategy and pricing.

Another major difference between the two corporations is the role played by Elon Musk. He is the figurehead and primary advocate for both SpaceX and Tesla. At SpaceX, Musk serves as CEO and CTO and works directly on different project teams. In this role, Musk is extremely influential in both the overall mission of the company and the day-to-day operations. Also, as founder of SpaceX and Tesla Motors, Musk has a close personal attachment to the companies and their success. Musk did not found SolarCity. He invested in the company in 2006 and became its chairman (Anderson, 2012; Studt, 2007). This creates more of a business relationship, rather than a personal one, between Musk and the company. His role as chairman makes his involvement more passive, which is in stark contrast to his involvement with SpaceX and Tesla. Despite these differences, all three companies have achieved great success in a short period of time.

Elon Musk's Personal Values and Resources

Although evaluating the success of Elon Musk and his ventures is essential for conducting this case study, it is also important to determine factors that play a role in his success. Haobai, Jing, and Jiming (2009) discuss a study that analyzes the relationship between a social entrepreneur's personal values and their success. The authors' findings demonstrate a positive correlation between personal values and organizational performance (paraphrasing Haobai et al., 2009, following "Conclusion"). Comparing these results with Elon Musk's personal values and leadership style finds that he exhibits many of the same characteristics as other successful social entrepreneurs.

Of the five major value types presented by Haobai, Jing, and Jiming (2009), Elon Musk is primarily characterized under the social and economic types. His three current ventures all focus on solving major social issues. However, as Musk states it, "if we don't have a profitable company, we will soon cease to exist, and that would be the end of it" (Canan, 2009, p.2). Thus, Musk has structured his companies to address social issues with an emphasis on being profitable. This is important because profits enable companies to continue to innovate (Dees, 1998). From a leadership standpoint, Musk primarily falls on the selling and participating end of the spectrum. He has been very successful at selling his vision for clean, sustainable energy to his employees and consumers. He does not simply advocate these goals though; he works closely with the teams to craft the solutions to them. As the positive correlation shows, these personal values and leadership styles seem to be contributing factors to the success of SpaceX, Tesla, and SolarCity.

Many social organizations often need outside funding because of an “inability” to recoup their costs (paraphrasing Haobai et al., 2009, following "Literature Review"). Elon Musk’s ventures have not needed as much external funding as other startups because he became very wealthy for his work with Zip2 and PayPal (Studt, 2007). This available capital is in stark contrast to what other social entrepreneurs are able to raise via methods such as crowd funding and donations (Dees, 1998; Szaky, 2012). The combination of prior capital and a commitment to producing low-cost products has enabled all three corporations to operate successfully in a manner that many other fledgling social ventures cannot achieve.

Conclusion

These findings suggest that Elon Musk is structuring his resources and knowledge to create novel and sustainable solutions to major environmental issues. The combination of prior experience from founding lucrative companies, personal values and leadership qualities that are representative of successful social entrepreneurs, and a desire to solve pressing social issues, has contributed to Elon Musk’s current entrepreneurial achievements. SpaceX’s motivation to expand interplanetary travel in anticipation of diminishing resources has given rise to more sustainable spacecraft construction and the increasing possibility of fully reusable launch vehicles. Tesla Motors and SolarCity are advancing humanity’s ability to use solar and electric power to create more sustainable living situations. One of the most important parallels seen between all three of these ventures is that of lowering costs in order to facilitate mass adoption of the new technologies. Elon Musk makes it clear that he believes that individuals have the right to access these sustainable technologies and the more people who adopt them,

the better off the environment will be. Another important factor has been Musk's ability to instill his vision for a sustainable energy future into each of these corporations. By maintaining a balance between solving social issues and remaining profitable, he has set up his companies to succeed over an extended period of time. Elon Musk's work at SpaceX, Tesla Motors, and SolarCity has contributed to the social entrepreneurship research space, and his success serves as a framework for other social entrepreneurs to base their social ventures upon.

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