Global Challenge Scholars Programme (GCSP) Portfolio

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Chapter 1: Introduction and the Global Challenge Project

Through this GCSP project, I hope the grand challenge of **restoring and improving urban infrastructure** is, albeit only a little, closer to realization. I hope that this GCSP project will continue on to inspire other engineers in solving problems for the disabled with lower incomes living in urban areas. Learning from my teammates, mentors and other experiences I gained from other projects, I managed to contribute to this project by designing and making a working prototype to test the concept. Infrastructures last for decades but the needs of users may change. Hence, there is a need to improve upon older infrastructures. The responsibility of improving the current infrastructure has to be at least partly borne onto the new generation of engineers. One improvement which was made evident to me through my GCSP project is the need for older buildings to be modified to accommodate for wheelchair users. Despite the regulations and legal efforts, there are wheelchair users who are left out. Although these users may not be the majority of the population, there is a real and dire need to have customisation of retrofitting in older infrastructures to allow the older buildings to continue to serve its purpose.

In the city state of Singapore, a major urban infrastructure is the public housing. Overseen by the Housing and Development Board of Singapore, more than 80 percent of the resident population is living in public housing flats (Housing and Development Board, n.d.). Older public housings, much like many other infrastructures, need to be modified and improved to better serve the current needs for their users. Specifically, the older public flats need to be modified to cater for wheelchair users. The population staying in the older public housing flats may be new wheelchair users. The residences may find themselves reliant on a wheelchair due to age or an age related condition as the average age of the residence increases.This correlation between age and mobility has been reported in the third Enabling Masterplan in Singapore as well as worldwide in the World Report on Disability (Fam et al, 2016; World Health Organisation (WHO), 2011). Thus, A major problem arises when these new wheelchair users are unable to navigate around the older public housings they have called home for decades. This is a problem specific to older public flats which were built before stringent building codes were enforced to ensure accessibility for wheelchair bound individuals in buildings. An example of a condition faced by those staying in older public housing flats are the presence of a few steps in front of their front door, as shown in Figure 1.

Figure 1. Doorsteps at front door of flats at Ang Mo Kio.

Wheelchairs cannot overcome the steep steps. Moreover, a ramp cannot be placed at a safe angle due to the narrow corridor (Tay, Teo, Khang, Thanh & Chong, 2017). Hence, there is no means of entering or egressing the flat unit for wheelchair users. In my GCSP project, the specific problem of wheelchair users overcoming these doorsteps in flats independently without the assistance of a caregiver is addressed. The aim of this project is beyond a mere exercise in education, but to bring a viable solution to a real problem faced by people today and possibly by the people of tomorrow. The problem statement came from the local non profit organisation SPD. The problem statement came from a real pain by the community staying in older public housing flats. The current recommended solution by SPD would be to have the wheelchair users relocate to a new flat with no doorsteps as obstacles. However, such change is too drastic and a better solution is required. Hence, there is a real need which my GSCP project is trying to solve.

The project examines the use of a winch system to lift or lower the wheelchair and its user along a ramp specially designed in this project as shown Figure 2. When not in use by a wheelchair user, non-wheelchair users can climb up the stairs to enter the house as per usual.

Figure 2. Prototype setup.

The above solution is a viable improvement in transforming urban infrastructure in Singapore to be more accessible for wheelchair users. Making Singapore more accessible to people with disabilities is necessary to allow independence in the portion of society with special needs. Initiatives like ours hope to allow the whole of society to have options in their lives without being limited due to infrastructure constraints.

Working on a project with the nature of improving on past designs made me aware of the long term impact of engineering design. While we cannot perfectly predict how our designs will impact users in future, I strive to consider holistically potential problems that may be encountered and work to minimize them.

My reflection of this project is elaborated in the following chapters. In Chapter 2, I will elaborate on my interdisciplinary experience in my GCSP project. In Chapter 3, I will explain the entrepreneurship aspect of this project. In Chapter 4, I will describe how global awareness on my part influenced my

contribution to my GSCP project. In Chapter 5, I will highlight the service learning aspect of this project.

Chapter 2: Interdisciplinary Experience

While working on my GCSP project, I drew on several skills and knowledge beyond engineering fundamentals. Specifically, the concepts behind design thinking, computer science, business and medical equipment standards influenced my work in my GCSP project. These tools were acquired through my formal education in university as well as from my past experiences working on other projects.

Design thinking in Engineering

Design thinking is a tool used in approaching problem solving. One of the key concepts of design thinking is user centric design, where understanding the interaction between a human and the solution is pivotal in designing a solution. I was first introduced to the concept of design thinking through the innovation & Design-Centric Programme (iDCP) in my university - the National University of Singapore. In this programme the concept of design thinking was instilled into me via hands on project work over the course of 3 years. Unlike regular modules where theory and application of engineering principles is emphasised, the more subtle skill of understanding human behavior is taught in the iDCP. We learned the importance of empathising with the users we design for, and how to gather feedback from the target users.

In my GCSP project, the concept of design thinking for user centric design was put to practice. We had tested our prototype, gathering first hand experience to how the user will use our solution. During initial testing stages I sat in a wheelchair to test out our prototype as a wheelchair user. I felt, albeit insignificant in comparison to real wheelchair users, frustration of having to rely solely on my upper body to navigate around. Moreover, we had a actual wheelchair user, Mr. Mano, test our prototype and gathered his feedback (see Figure 3).

Figure 3. User testing with Mr Mano at Enabling Village, Singapore.

Mr Mano's feedback was enlightening and crucial in shaping the modifications to be made to the current prototype. For example, Mr Mano highlighted the need to prevent the users from holding onto the back wheels the wheelchair when the winch system is in operation. Regular wheelchair users tend to control the movement of their wheelchair via the back wheels of the wheelchair. A user may attempt to control the wheelchair by holding onto the back wheel out of habit. However, this will cause the wheelchair to go off balance as the wheel does not freely roll according to the pull of the winch. This insight, and many others like it, may not have been discovered without user testing or other means of understanding the user.

Through this project I also became more aware of the obstacles wheelchair users face. The awareness that we share public spaces and pathways with wheelchair users grew inside me. Even in my mundane life, I began to notice that there were many physical barriers for wheelchair users, and how designs are often retrofitted to accommodate their unique needs. For example, in case of fires, newer buildings have holding stations at stairwells for people with disabilities who cannot escape via the stairs.

Computer Science in Engineering Solutions

Through the iDCP, I was also part of several group projects, all of which are multidisciplinary in nature where I had to team up with engineering students from departments other than my home department of Mechanical Engineering. Many of which exposed me to the field of Computer Science. For example, in my third year I was in the Hydrone project under the iDCP aiming to develop an aquatic drone. In the Hydrone project, I not only worked with fellow students from the Faculty of Engineering but also with students with Computer Science backgrounds.

Having worked closely with students from the school of computing has improved the way I approach problems. Some problems which require complex mechanical solutions, could be easily solved using a software based approach. By knowing the limits and possibilities of computing, I can gauge whether a software or a hardware solution would be more appropriate. This experiential knowledge helped in my GCSP project. For example, it would require an intricate mechanical design to control the speed of the wheelchair traveling down the ramp, but takes only a few lines of code to control the winch speed using a software based approach.

Moreover, I took up a minor in Computer Science to supplement my Mechanical Engineering major. I took several interesting modules which shaped the way I approached problem in my GCSP project. For example, in a module on networking I learnt how the internet works. My theory from Computer Science equip me with the base knowledge required to appreciate the complexities of controlling the system completely via the internet. This awareness helped in my GCSP project in which I suggested the more reliable means of control using radio frequency to control the winch system for the prototype of my GCSP project instead of a internet based controls system.

The Business Perspective in an Engineering Solution

I have also worked with students from other faculties for my co-curricular activities. For example, I teamed up with a couple of Business students in the Wake Up Your Idea (WUYI) hackathon where we proposed an incentives-based reward system to promote academic excellence in disadvantaged youths.

Under the aforementioned Hydrone project I also participated in the Intel Invent 50 competition which required some business planning.

Working with teammates from a business background brought to my attention the need for a business model to ensure the growth of a project in the long run. I learned about key concepts of business by actively joining team discussions about the business aspect of our project. By observing the nature of their questions, asking questions of my own and listening to their explanations, I gained a better understanding of the business point of view. By going through possible business plans together, I learned about the different business models commonly adopted.

Through my experience with my teammates with business backgrounds, I can incorporate an entrepreneur elements into my projects. The entrepreneurship skills I applied in my GCSP project is elaborated in the subsequent chapter, Chapter 3.

Furthermore, the points learned from having the business point of view can be incorporated into the technical work of a project. For example, understanding the market size is crucial in deciding the commercial manufacturing method. For example, a large market size, requiring large volumes of a part may call for injection molding. On the other hand, if the part is only required in the hundreds, the cost of making a mold required for injection molding would not be justifiable. Moreover, when considering the market type, we may consider manufacturing methods which allows for customisation of the system to fit the unique needs of each user.

In the case of our project, the design of the solution is also done for ease of installation, with minimal drilling or permanent modifications. The whole process of setting up the system should not exceed a day. Drilling is minimised by clamping parts of the system onto existing structures (Tay, Teo, Khang, Thanh & Chong, 2017). Moreover, modularity in the design allows components to be easily replaced in case of upgrades or for maintenance purposes. For example, the winch should be replaceable if necessary without having to remove the whole system.

To commercialize our product, certain certifications and criteria must be met. For example, we must be compliant to the Building and Construction Authority (BCA) codes applicable to all buildings in Singapore. The components and modifications made must also be certified safe. For example, the winch used must be certified for this specific application to ensure the safety of the users.

Overall, the varied experiences in several non-engineering fields allowed me to better contribute to my GCSP project. This also highlighted that knowledge from other fields can help in improving an engineering solution.

3. Entrepreneurship

From Chapter 2, I have expressed how my past projects have influenced my business awareness.

The importance of having a rough business plan in mind is important as the project progresses from the initial stages of proving a concept was highlighted as I worked with business students.

The Gap in Needs

At the earlier stages of all my innovation and Design Centric Programme (iDCP) projects, such as Hydrone project, market research has been pivotal in deciding the direction of the project. This step helped in identifying a specific need to tackle and defines the problem statement. For example, at the beginning of the Hydrone project the team was set on building an unmanned aerial vehicle. However, the novel concept of having an aquatic drone was conceived after talking to experts in the field and researching the current market.

In my GCSP project, I used the skills I learned from my iDCP projects in analysing the current market to identify a means of solving the problem posed. Extensive market research was done to verify the lack of a solution for the specific problem posed - for wheelchair users to overcome the doorsteps in public housing flats (Tay, Teo, Khang, Thanh & Chong, 2017). Hence, there is a need that is not satisfied in the market. The team also worked with an established organisation dealing with wheelchair users, Society for People with Disabilities (SPD), to verify this specific market need. Upon deciding on a concept, patent research was done to ensure that the solution, if implemented does not infringe existing patents (Tay, Teo, Khang, Thanh & Chong, 2017).

Target Market

Furthermore, the target market must be kept in mind when designing a solution. For the case of the Hydrone project which aimed to provide aquatic drones, the target market of port authorities such as the Maritime Port Authority in Singapore was identified. Due to the nature of such organisations, the pricing of the solution was less of a concern over the quality and reliability of the products.

In contrast, the WUYI hackathon project which aimed to persuade youths to excel academically using a reward method, called for a different business approach. The key focus was not to generate profit because of the social service nature of the project. Instead, sustainability of the project focused on generating sufficient income to cover the costs incurred. We had a high cost required to run the project, and there is no remuneration for the outcome of the project. Therefore the business plan was to develop the project under an umbrella organization with funds for furthering the same cause. Hence, we decided to work closely with Beyond Social Services for our project to raise funds via external parties to sustain the project.

In my GSCP project, the target users are defined by the nature of the problem, thereby focusing on wheelchair users who stay in public housing flats with doorsteps. However, the question of who is to pay for the solution proposed needs to be identified to gear the project in the corresponding direction. For example, if the users, that is the flat owners and wheelchair users, are to purchase the proposed solution the cost of the solution must be at the lowest cost because the target group are unlikely to be

willing or even able to afford an expensive solution. In contrast, if the government is to cover the costs of the project, the focus would deviate towards reliability and scalability in the long run of the project.

My GCSP project geared towards having the users afford the solution by themselves, thereby the solution is kept at a minimal cost and also to be sold at a lower price margin. The design of the solution is influenced by this decision to be low cost. Therefore, the solution proposes a simple winch mechanism, which is available at a lower cost. Alternative solutions which require more complex mechanisms such as stair climbing wheelchairs are not considered as they are expensive and redundant in functions (Tay, Teo, Khang, Thanh & Chong, 2017).

A reason as to why I suggest having the users pay for their solution is due to the difficulties faced during the WUYI hackathon project to receive funds from external parties. Requesting for funds may lessen the financial burden while providing an advanced solution but such funds are not guaranteed. Moreover, the time taken for the funds to be secured may be long and users may have to wait for some time before the solution can be deployed.

Comparing the business model for the profitable Hydrone project and the WUYI hackathon project, my GCSP project takes after the WUYI hackathon project model in terms of the low profit margins. This is because of the similar social service aspect of the two projects, where sustainability is the main concern rather than maximising profits. However, the Hydrone project is also similar to my GCSP project in that there is a profit to be made albeit in much lesser amount. Hence, my awareness of both business models were applied in suggesting a business model for my GCSP project.

Services versus Products

From an engineering perspective, there is a need to identify the business model of the solution, whether the solution is better to be sold as a service with subscription or as a stand alone physical product. For example, my involvement in the Hydrone project to build an aquatic drone under the iDCP for the Intel Invent 50 competition geared towards a service based subscription business model. The drones would require hardware maintenance, and our electronics and software may require constant updating. A licensed pilot may also be required to fly the drones, which the customer may not have access to. Hence, a service based business model was suggested as a potential business plan to provide the necessary services which accompanies the aquatic drone. This decision allows for complex functions to be implemented into the drones if necessary as the pilots will be knowledgeable experts from our team.

On the other hand, for my Final Year Project under the iDCP, the project aims to sell products as stand alones, without the need of a service subscription. The project aims to design robots to inspect rail tracks defects. Therefore, the target customers are the mass rapid transit companies, who have technicians highly qualified to operate the robots. Hence, the project will provide training for the customers or infrequent part replacement when needed but a subscription to a service would not have much value added from the perspective of the customers. Hence, the robots would be best marketed as a stand alone physical products. Therefore, the robots are built and designed to be easy to use for the technicians, not requiring elaborate instructions else the robots may not be used in the intended manner.

Based on the two approaches discussed above, my GCSP project would be more suitable for the service-based model where customers would subscribe to our services at a quarterly or 6 month long period. Services we could potentially provide includes regular maintenance and upgrades. Providing good service to customers would incorporate feedback collection to constantly improve the product, as user centric design values user feedback as discussed in Chapter 2. Moreover, the users may not be technically apt or equipped to troubleshoot if an error occurred. They may also be inclined to skip maintenance works such as oiling of mechanical parts. Poor maintenance may cause the system to be less reliable over time. Hence, a service based model would be more appropriate for the commercialisation of this GCSP project.

4. Global Awareness

Wheelchair accessibility as an important global issue

My GCSP project aims to solve the issue of wheelchair accessibility in the context of doorsteps in front of public housing flats. This specific problem is a part of a bigger global challenge of ensuring wheelchair accessibility. On a global scale, there is a need for infrastructure to accommodate for wheelchair users. This is because the subpopulation of people who require a wheelchair account for a significant portion of the world's population, with 1 in 100 of people requiring a wheelchair (WHO, 2010). Excluding wheelchair users in design of infrastructures would limit their mobility; thereby further restricting their ability to contribute to the productivity of society as a whole (WHO, 2011). The problem is aggravated if this subpopulation cannot live independently, requiring the help of a caregiver. Caregivers would be forced to reduce their number of working hours to care for the disabled; in some cases having to quit their jobs to give full attention to their beneficiaries (WHO, 2011). Hence, beyond the need for mere accessibility, the independence of the wheelchair users to move around without assistance of others is required.

Accessibility for wheelchair users in Singapore

In Singapore, there are currently building codes which requires new buildings to be built according to standards which allows safety and accessibility for wheelchair users without necessarily relying on caregivers. These codes - compiled by the Building and Construction Authority - ensure that there are ramps and lifts for wheelchair users to navigate in or around buildings (Building and Construction Authority, 2013). However, since there were no regulations in the past, older buildings may not be accessible for wheelchair users. An example of such a case is highlighted in this project where steps before the front door of flats were introduced. Some other examples of wheelchair obstructions include steeps slopes, narrow pathways and doorways, slippery surfaces and so on. Temporary features such as temporary pedestrian pathways at construction sites may also pose as an obstacle for wheelchair users.

Accessibility for wheelchair users in Malaysia

As a Malaysian I grew up in Malaysia and lived there for over 18 years. During my time in Malaysia, I realised there were some places which were not very accessible for wheelchair users. As I grew up in a

tourist city of Melaka, I realised that some tourist attractions such as the historical sites of A Famosa and St. Johns Hill require scaling steep stairs, an impossible feat for wheelchair users. Some older buildings also do not have lifts but only steps and narrow stairs. However, newer buildings such as malls are very wheelchair friendly and may even lend out wheelchairs to older customers who are unable to walk around to shop.

In Malaysia, the Persons with Disabilities Act 2008 requires buildings and other public facilities to be equally accessible for both the able bodied and the disabled, in junction with the concept of universal design where inclusion of all is required in design (2008). This act is also applicable to existing buildings, where current buildings are required to perform modifications to meet the requirements of the act.

There are also standards to abide by for ensuring a universal design is achieved such as the 2002 Code of Practice on Access for Disabled Persons to Public Building by the Department of Standards Malaysia (2002). The building standards imposed are similar to the Building and Construction Authority codes, both specifying design requirements to ensure accessibility for the disable and by extension, wheelchair users. However, the implementation and execution of said standards in Malaysia can be improved upon (Kamarudin, Hashim, Mahmood, Ariff & Ismail, 2012; Kadir & Jamaludin, 2012). There still exist older structures which can be further improved on their accessibility to wheelchair users (Kadir & Jamaludin, 2012). Such retrofitted modifications are similar to the situation being highlighted in my GCSP project which aims to overcome an existing wheelchair obstacle in older buildings.

Accessibility for wheelchair users in Hong Kong

I spent a semester in Hong Kong under a student exchange programme at the Hong Kong University of Science and Technology in 2016, where I was exposed to the infrastructures available and the overall nature of moving around in Hong Kong. Being a very densely populated and fast paced in the city, I found that despite being able bodied, moving around in the city was very tiring. Being a wheelchair user must be even more taxing and inconvenient due to the tightly packed and active crowds. In terms of infrastructure, I notice a fair amount of wheelchair friendly buildings. Malls are especially ubiquitous in Hong Kong, and a cluster of malls often are linked to one another via sheltered pedestrian bridges so wheelchair users and walking pedestrians alike can move from one building to another with ease. Moreover, a train station is often very accessible from said malls.

Similar to Singapore and Malaysia, Hong Kong has regulations to ensure wheelchair users via the Design Manual Barrier Free Access 2008. Practices are separated into mandatory requirements and best practices. Therefore, the basic requirements are compulsory to implement but some suggestions are also given to ensure better accessibility if desired. Hong Kong has had codes to promote universal design since 1997, with the Design Manual: Barrier Free Access 1997, and this newer manual serves as an update to the previous manual to account for the aging population in Hong Kong.

In Malaysia, Hong Kong as well as Singapore, the governing bodies have acknowledged the need for wheelchair accessibility by drafting acts and regulations in ensuring that infrastructures are designed with people with disabilities in mind. In addition to following the set rules and regulation when

building new infrastructures, we are also required to improve on the accessibility of current infrastructures. My GCSP project aims to improve the accessibility of a current infrastructure, specifically, public housing flats and in doing so, play a part in addressing the bigger issue of wheelchair accessibility worldwide.

5. Service Learning

I contributed to several volunteer groups throughout my four years in NUS. Under the NUS Community Service Club and the Eusoff Volunteer Corp, I volunteered to help the elderly with their household chores and other activities. My main takeaway from the experience is realizing the conditions these low income elderly are living in. Their flats are small, often one-room HDB flats. Some of them could not leave their homes in fear of falling down or due to pain in their leg.

These experiences brought me to realize the gap between available technology and users who may not afford them. Because of the lack of exposure to newer technologies, elderly, especially elderly from low income backgrounds are not introduced to today's technology which could benefit them. Take for example, there are devices currently commercially available which allows the blind or illiterate to read. The commercially available Optical Character Readers, OCRs, processes the written language on paper or print and subsequently reads them aloud (Freedom Scientific, Inc, 2017). Such a device would allow the blind and the illiterate to read personal letters or bank statements without the help of a middle man. Despite the existence of such devices, the elderly I met during my volunteering experience who have sight impairment or are illiterate depended on volunteers to read personal letters. This required the elderly to trust the volunteers, as the letters usually contain private information and there is no means for the elderly to verify if the volunteer is truthful or otherwise. Such complications can be avoided with the use of commercial technology of the aforementioned optical character readers. Yet, such devices are not an option for the elderly in question. There are several reasons to this. A jarring factor being the monetary cost of such devices are beyond the limited budget of this target group. In short, although the technology may be available, they are not reaching the portion of society that need them the most. Hence, I would like to engineer solutions for these groups who may not be able to afford the high cost of the technology despite needing said technology.

There are several approaches which can bridge the gap between available technology and the lower income people who can benefit from it. One method would be to find a innovative means to reduce the cost of manufacturing high technology devices. Alternatively, another approach would be to adapt existing mature technology to satisfy the need without using expensive technology. In my GCSP project, the latter approach was more applicable.

The project proposes the use of a winch system, which is a well established technology. This helps to reduces the costs of the design. Additionally, the technology is stable and well tested, resulting in a system that is more reliable and safer. In summary, through working on my GSCP project I have a better understanding and awareness about the real and current problem of accessibility of wheelchair users in infrastructures, while being driven to design frugal solutions to meet the needs of the lower income subpopulation.

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