# Learning from failure: Developing a typology to enhance global service-learning engineering projects.

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## Introduction

Courses and programs that focus on sustainable community development, global service learning, humanitarian engineering, and related themes have gained considerable prominence in engineering schools[1-3]. In many of these programs, students respond to a problem situated in an international context over the course of one or more semesters, and may also travel abroad to deliver a designed product or solution.[3] The projects undertaken by engineering students in these courses and programs are highly influenced by the context in which they are situated. Further, the success or failure of these projects relies in part on whether or not engineers substitute the typical technical rationality approach to problem solving for one in which they continuously conduct a "reflective conversation with the situation" (p. 76).[4]

However, engineering students and educators often lack the training and the support to approach the sociocultural aspects of their design work[5], and many projects fail, doing more harm than good to partnering communities. Engineers Without Borders (EWB) Canada is one of the first organizations to report on their own failures in their annual Failure Report[6], and they have also maintained a web site (Admitting Failure, http://www.admittingfailure.com/) that encourages development-oriented workers and organizations to document and discuss failure cases. On this web site, the failure stories include two main sections: a description of the failure and the learning that resulted. Similarly, texts such as Lucena et al.'s *Engineering and Sustainable Community Development* features many insightful examples of engineering projects that did not succeed.[2] Many other cases are available on the Internet, in databases, and in other published literature. Yet, no one has attempted to systematically analyze and categorize these failures to create a typology that enables practitioner to learn from their own and other's mistakes.

In this study, we take the first steps toward creating a failure typology that can help engineering students and practitioners avoid negative outcomes of their design. My guiding questions are: 1) what types of failures occur in humanitarian and similar engineering projects?, and 2) what can we learn from these failures? To address these questions, we collected cases of failed projects from a variety of print and online sources. we analyzed the cases and inductively constructed a typology to classify the occurred failures. In the sections that follow, we first present the inclusion criteria we used to select cases and what procedure we employed to analyze them. we then introduce the failure typology and discuss how each case reflects a certain mode of failure. Finally, we conclude the paper suggesting some strategies to avoid such failures.

## Methods

### *Case Selection*

In this study we take first steps toward creating a typology that categorizes common failures in humanitarian and similar projects. In order to achieve this goal, we selected cases based on the following inclusion criteria: 1) the case must discuss an engineered product or process, 2) the failure discussed in the case was not due to a technical problem with the product or process, and

3) the case described a small- or medium-scale project. The first two criteria were adopted because engineering already has powerful instruments to understand and quantify technical failure, e.g., FMEA and Fault Tree Analysis. However, engineers lack a similarly comprehensive and powerful typology to understand the more qualitative aspects of failed projects. The third criterion was used because the study targets students who are enrolled in service-learning courses or are affiliated with organizations such as Engineers Without Borders. The projects undertook in these situations are usually on a small- or medium-scale.

The study is exploratory in nature and involved searching for and identify eight relevant cases from following sources:

- The Admitting Failure web site (admittingfailure.com), where development workers from various backgrounds post their experiences of failed projects.
- The EWB-Canada Failure Report, an annual report were volunteers of EWB Canada report their own stories of failure. EWB Canada also maintains the Admitting Failure website cited above. However, the cases in these two sources are different.
- The Global Engineering Design Symposium (GEDS) at Purdue University, a half-day workshop which covers topics such as global competency, trans-disciplinary teamwork, human-centered design, and stakeholder/needs analysis.[5] The symposium features presentations, panels, and analysis of case studies.
- Internet blogs and university web sites. Lucena et al.'s *Engineering and Sustainable Community Development* also cites some of these sources.[2]

*Case Analysis*

Initially, we searched the literature for existing typologies, and then we attempted to classify the collected cases based on the existing typologies. Two failure typologies were identified. The first one was proposed by Ika and is comprised of four project management traps that major development agencies encounter.[7] The first of these involves a "One-Size-Fits-All" approach that "assumes all types of project and project models share the same characteristics" (p.33)[7]. The second trap involves an "Accountability-of-Results" approach that is "too focused on reporting to external stakeholder audiences and too little on using performance information in internal management decision-making processes to achieve better results" (p. 34)[7]. The third trap is the "Lack-of-Project-Management Capacity," which emphasize the lack of investment in project supervision. The last trap is "Cultural", which highlights how many "development interventions fail to take into account major decision makers, fail to address the problem of rationality, and fail to account for the lack of local commitment that leads to projects being considered "donor" projects rather than "local" projects" (p. 34)[7]. Among Ika's four traps, the "Cultural" Trap is the most relevant to the cases reviewed in the present study. In fact, all of the collected cases probably can more or less fit in such category. However, the cases also contain nuances that are not fully described in Ika's framework. Consequently, Ika's typology was deemed inadequate. A second typology of interest was proposed by Fortune and White[8]. Their failure framework is based on the "Formal System Model" that comprises "a decision-making subsystem, a performance monitoring subsystem and a set of subsystems and elements which carry out the tasks of the system and thus effect its transformations by converting inputs into outputs" (p. 54)[8]. The framework is very comprehensive and includes considerations such as "user/client

involvement" that are very relevant to the cases in question. However, Fortune and White's framework, like Ika's did not adequately address all the nuances characterizing the selected cases.

These two typologies are very insightful and interested scholars are advised to learn from them and apply them in their work. However, since they were not appropriate for this study, we analyzed the cases inductively to create a new one. we coded the cases for relevant themes. Each theme constitute a failure category. Two overarching failure category were found: 1) failure to learn, and 2) failure to apply knowledge. The "failure to learn" category was then divided in three sub-category: 1a) failure to assess needs, 1b) failure to understand the culture, and 1c) failure to assess assets. Then, we grounded each category in relevant literature from a variety of disciplines. To verify the categories the co-authors met regularly, discussed, brainstormed, reviewed relevant literature, and regularly consulted an anthropology professor who has extensive experience in the development sector.

*Overview of Selected Cases*

Table 1 summarizes the relevant cases of failed engineering projects for development, including a brief description of the engineered product, process, or service, and its mode of failure. In the following pages, we describe the cases in more details and unpack the failures related to each case.

**Table 1.Cases summary and modes of failure**

| Case name & code | Engineered product, process, or service | Modes of failure |
|---|---|---|
| Smokeless Ethanol Stoves (SES)[9] | Ethanol-fueled stone burners to eliminate unhealthy smoke from burning wood | Failure to assess needs |
| The Stranger's Eyes (TSE)[10] | Installation of mill to grind grain | Failure to assess needs |
| Women Bread Making Cooperative (WBMC)[11] | Clay oven to produce bread | Failure to understand the culture |
| Solar Cookers Project (SCP)[12] | Solar cookers to eliminate the need of firewood | Failure to understand the culture |
| Fish Factory Project (FFP)[13] | Fish factory to alleviate consequences of drought | Failure to understand the culture |
| Government Service for Rural Citizens (GSRC)[14] | Computer kiosks to help provide better access to government information and services. | Failure to assess assets |
| Customer Service (CS)[15] | Mechanization of business operations with a planning machine | Failure to assess assets |
| Village Improvement Project (VIP)[16] | Nursery for the woman of the village | Failure to apply knowledge |

**Findings: Modes of Failure**

By inductively analyzing the cases, we found that failures were due to 1) *failure to learn,* which refers to a lack of knowledge or failed attempt to learn about the context, and 2) *failure to apply knowledge* about the context when proper knowledge was properly gained. The failure to understand the context was then divided in the following sub-categories: 1a) failure to assess the needs, 1b) failure to understand the culture, and 1c) failure to assess assets. In this section, we

review relevant literature that inform the proposed failure typology and explain how each case belongs to one of the aforementioned categories.

*Failure to Learn 1a: Failure to Assess Needs*

Needs can be defined as the gap or discrepancy between an existing conditions and the desired or preferred condition. A problem with such a definition lies on the question of "Whose reality counts?,"[17] especially when it is time to decide which condition is desired or preferred. As evidenced by a long history of failed development projects, Westerners often arrive in poorer communities with a plan and fail to assess whether their project is indeed perceived as needed by the community.[2,18] They see problems based on their Western standards and do not listen to what the community has to say. When the development professionals go back home, they leave a community with broken and unneeded "solutions." Consequently, projects inevitably fail and create more problems than solutions when engineers do not acknowledge that what a community perceives as needed is the *real* need of the community,

In the Smokeless Ethanol Stoves (SES) case, a group of engineering students observed a health issue in a community and engineered a solution.[9] However, only after developing the solution did they find that the community did not perceive the problem they were trying to solve as a real problem. The engineered solution was an ethanol-fueled smokeless stove, which had to replace the hazardous firewood stoves:

> The final product was a round, insulated, approximately 20-inch-high single burner device with a fuel tray insert on the side and a flat top. It was smokeless, odorless, clean, and efficient. The stove itself was significantly more efficient than a similar prototype that had been developed in South Africa, and the gelled ethanol was about five times cheaper than the ones being marketed in Accra, the capital of Ghana.[9]

In addition to the fact that 10 to 21 individuals comprised the typical family and that ethanol was still more expensive than wood, the main problem with the project was that the community members did not consider smoke as an issue:

> Smoke was part of daily cooking – they did not perceive it as a health problem. Adopting the improved stoves would mean changing their lifestyle, habits, values and interests. So they were not ready to fix a problem they felt did not exist for them.[9]

Because the community members did not see the health issue and did not feel the need for new stoves, the smokeless, odorless, and more efficient stoves were never installed.
While the engineers of the SES tried to solve an observed problem that the community did not perceive as such, Pierre, the protagonist of The Stanger's Eye (TSE), arrived with a pre-defined plan to install a mill to grind corn without bothering to ask whether the community truly needed the mills[10]. As reported by Carlson, the village already had a mill and the construction of another mill caused even more problems:

> Pierre came as a stranger to Kafinare, asking no questions. It was nearly a month before he realized that he was putting a mill directly across the road from the existing one. In true Kafinarian fashion, no one told him that we already had one because he had not asked. When the truth eventually dawned, he protested in some shock that he would never have dreamed of running the enterprising villagers out of business, but then he plunged ahead with the plans on ORB's drawing board. So much for felt needs.[10]

On top of proposing an unneeded "solution," Pierre's project was characterized by a lack of cultural understanding, which is the core of the failures described in the following section.

*Failure to Learn 1b: Failure to Understand the Culture*

The second failure mode occurs when engineers only focus on the technical aspects of their project while overlooking the role of culture in the production and implementation of technology. In this study, we leverage Lucena's[19] and Downey and Lucena's[20] "dominant images" framework to define culture: "[I]ndividuals living and working in a particular spatial and temporal location are challenged by dominant images. Dominant images create expectations about how individuals in that location are supposed to act or behave. In this … concept of culture, the image remains the same over a period of time, while individual or group reactions to the image's challenge might differ" (p. 5).[19] Such dominant images then influences the rules, assumptions, definitions, values, and expectations that people use to organize and understand the world around them. For example, different dominant images influence the gender-roles in a household, how money is managed, acceptable behaviors, how people are organized, etc. For a project to be successful, the sociocultural and demographic characteristics of the community and the cultural acceptability of the projects must be fully evaluated.[21-23]

A lack of understanding of the habits and customs of partnering community can deem a project to fail from its very beginning. This is the case of both the Solar Cookers Project (SCP) and the Fish Factory Project (FFP). In the SCP case, Mattias found out that wood, the primary cooking fuel in Kenya, was running out due to deforestation and there was a need to decrease firewood consumption of stoves[12]. To address this problem, he thought that that solar cookers – or stoves that cook food with solar panels – would solve the problem once and for all because they would eliminate the need for firewood. However, he soon understood that this solution was not possible due to cultural customs related to cooking in open air:

> I realized that very rarely will the societies of Kenya or Eastern Africa in general accept to cook food in the open, for everyone to see, and with no fire. Indeed, one time while camping, we were physically threatened for cooking our food in the open – it is a strong taboo for several tribes.[12]

Consequently, although solar cooking appeared to be appealing, especially given the Western clean energy agenda, the solution proposed by Mattias was not culturally appropriate to the region and inevitably failed.

Likewise, the developing agency involved in the FFP case tried to solve the problem of the "whims of drought" by constructing a fish factory near a fish-rich but underexploited lake[13]. However, the development agency did not take into account that the community they were designing for was nomadic and perceived fishing as a low profile activity, and they preferred to raise cattle that were instead viewed as a sign of wealth. The factory was scarcely used and then abandoned. The project resulted in a waste of time and valuable resources, and did not provide any alleviation to the "whims of drought."[13]

While some projects fail due to reliance on culturally inappropriate solutions from the start, as in the SCP and the FFP cases, other projects can fail due to small but significant cultural differences that arise during the project. This is the case of the Women Bread Making Cooperative (WBMC) case described by Anthony, a Peace Corp Volounteer.[11] Anthony's story begins with a conversation he had with four women in his town about the possibility of building a clay oven to produce bread, as an alternative to the poor quality bread that was frequently imported from bigger city nearby:

> One day the women and I had a conversation about making bread. The only bread available in my village was brought in on a motorcycle from a bigger city about 25k away. The bread was terrible and it tasted like gasoline fumes yet people always bought it because it was the only bread they could find. The women said, we know how to make bread. We could do it and sell it in our village.[11]

Before they began collecting funds to start the project, they made sure the other villagers also felt the need for better bread. In fact, they did market research and found that most of the community members would have liked to buy their bread instead of what they were getting from the bigger city. Once all funding was collected, they built the clay oven and started baking. At the beginning, the project was a success. However, at one point the women stopped baking as scheduled and Anthony found out that they did not have enough money to continue baking. The project had failed. The reason for this failure can be found in Anthony's reflections:

> I was essentially their bank or their savings account in a culture where saving money is not done, let alone a priority. Yes, I could help with the planning and ideas but they had no where to safely store their money where their husbands and kids couldn't ask for it.[11]

As Anthony found out, many cultures handle money in different ways, and entrepreneurship ideas and practices may not be customary. Moreover, this case also illustrates that in some cultures it is not appropriate to deny money when requested, especially inside a household.

*Failure to Learn 1c: Failure to Assess Assets*

A third failure mode can derive from not properly evaluating the assets of the community. The most important asset of a community is their people, with their skills and knowledge. Additionally, people possess social capital: "the norms and networks that enable people to act collectively" (p. 227).[24] The social capital of a community allows individuals to better face poverty and vulnerability, resolve disputes, and take advantage of new opportunities.[24] Other

assets are the physical characteristics of a community such as its infrastructures, energy and waste resources, and financial situation. Moreover, it is important to properly leverage locally available natural resource, rather than importing from other countries. In order to avoid failures, projects need to harness community assets, while avoiding engineering solutions that require unavailable or unreliable assets.

The Government Service for Rural Citizens (GSRC) case describes a project addressing real needs in an apparently culturally appropriate way, but failed due to a lack of physical assets.[14] As described by Sanjay and Gupta, the State Government in Madhya Pradesh, India, installed a number of kiosks in "a village deemed to be living below the poverty line."[14] The kiosk provided many needed services such as updated information about market prices of agricultural goods, a service to provide tips for farmers, employment openings, an e-education site, and more. Although the projects were recognized internationally for being democratic, innovative, and transparent, the kiosk project did not work as intended. In addition to bureaucratic delays, rotation in the government staff in charge of the project, and a lack of financial sustainability, the project was especially lacking the needed infrastructure to succeed. As the case study explains, "The UPS batteries have a charge-up time between four and eight hours. But in some villages, there is only an hour or two's electricity per day, making Gyandoot operation only sporadic."[14] A thorough evaluation of the infrastructures of a community can prevent the investment of capital into a project that would be unsustainable as in this case.

The Customer Service (CS) case describes a failure due to the lack of a different kind of asset, namely the skills of the people involved.[15] The protagonists of this story were collaborating with a small carpentry shop to mechanize some operations by installing a planing machine. However, the machine broke soon after installation: "During installation, the agent incorrectly connected the machine to electricity and upon usage, one of the critical components was destroyed, rendering the machine useless" (p. 13).[15] They made the incorrect assumption that their targeted customers had the skills and the knowledge to set up the machine. Proper training or selection of customers would have avoided this failure.

These two examples show that when some important assets are missing, the projects will not work as hoped. However, it is important not to be misled by such examples. The most successful projects for development are often not the ones that requires new assets to be introduced, but those that properly harness the many assets that a community already has.[15]

*Failure to Apply Knowledge*

The cases reviewed so far failed due to a lack of understanding of the context in which they took place. However, as evidenced in the following, possessing the right knowledge is not enough if it is not applied when needed. In cases reported below, the main actors were able to assess needs, assets and knew well the culture in which they were operating. Yet when it was time to make salient decisions, they did not use the knowledge they had acquired.

The Village Improvement Project (VIP) case describes the story of Ed who knew very well about the culture, specifically the gender-role dynamics, characterizing the community, but failed

because he did not apply his knowledge.[16] The project was not a predefined plan as some of the previous cases, but was born from a request by some of community women:

> We had several community meetings that meandered (as they do) and generally seemed to reflect the dominant voices of men. However, at the end of one of these meetings, one of my extraordinarily talented Ghanaian colleagues from the University of Cape Coast had the experience and the awareness to quietly wander off to a group of women and chat with them. I noticed this but did not say anything. A few minutes later, he strolled by, and as he did he said to me "we need to build a nursery." Kofi had managed to elicit the womens' childcare needs, which were much more practical and actionable than any other plans we had heard. At the next community meeting we raised this, and nobody objected – we just got into wrangling over details.[16]

Ed went back to the village several times in the following years. However, the nursery was never built, nor construction ever even initiated. The reason lies in the gender dynamics that characterize the community. In fact, the men of the community were not interested in supporting an intervention that would raise women's income, even if this would have increased the total income of the household. In this case the failure was not due to a lack of knowledge on behalf of Ed, but a failure to use his knowledge about the culture when the nursery project was proposed:

> I know damn well that men get very itchy about anything that allows women to become more productive, as this calls one of the two goals of existing livelihoods strategies into question. Granted, I figured this out for the first time around 2007, and have only very recently (i.e. articles in review) been able to get at this systematically, but still, I knew this.[16]

The question that arises from this case is: once we learn about the context, how can we design solutions that are appropriate for the context? It is important to find a way to document what one learns during a project and to let the learning inform the decision-making.

**Conclusions**

In order to avoid designing an engineering project that harms a community, first one needs to understand why past projects have failed. The second step is to deploy strategies that can avoid such failures in the future. In this section we summarize the types of failure presented in this study and for each failure suggest some strategies that engineers and engineering students could use when designing for development. The intention of the literature review on different engineering design approaches is to provide interested readers with resources to improve their own practice. The discussion of pros and cons of such suggested strategies go beyond the scope of this study and is left to the diligent reader.

The failure categories that emerged from the analysis of the selected cases comprise: 1) *failure to learn*, which is further subdivided into failure to assess needs, failure to understand culture, and failure to assess assets, and 2) *failure to apply knowledge* once proper insight about the context was gathered. The failure to assess needs happens when engineers want to implement a new

technology that is not needed (as in the TSE case), or when they are trying to address a problem that is not perceived as such by the community (as in the SES case). The failure to understand culture happens when engineers take an ethnocentric approach in the project and fail to understand that culture has a deep influence on strategies of problem defining and solving[26]. The failure to assess assets occurs when engineers introduce solutions that require locally unavailable assets, such as specific skills, knowledge, and social capital of the community (as in the CS case), or physical infrastructure (as in the GSRC case).

Cernea underlines the need for *Putting People First* to avoid failure such as the one described in this study.[22] To do so, engineers should employ strategies that derive from different disciplines, such as sociology and anthropology.[22] A cost-effective way to do so is the Rapid Rural Appraisal (RRA) approach[27], which comprises a large set of methods, some of which include:

- *Secondary Data Review*: Published and unpublished documents such as ethnographic literature, blogs of people who had worked in the selected country, trip reports, etc.
- *Key Informants:* Local people who are willing to collaborate and who can provide insights regarding the local context.
- *Interviews:* Including semi-structured or unstructured interviews and focus groups.
- *Transects and Group Walks:* Systematic walks outside existing roads, streets, and other routes.
- *Stories, Portrayals, and Case Studies:* Anecdotes from the local people about their own and community history, which may unveil strategies that they have been using to face current and past challenges.

These methods are suitable when outsiders have short time and need to quickly understand the context of their project. This might be the case of EWB students, who usually have a short time to evaluate the feasibility of their projects. Likewise, engineers could utilize the method of "Go and See" developed by the founder of Toyota.[28] This approach allow practitioners to understand a problem from the perspectives of all the involved stakeholders.

However, various scholars have argued that methods such RRA and "Go and See" are limited and that the success of projects depends on the participation of the community members. Chambers proposed to use Participatory Rural Appraisal (PRA) techniques that "enable local people to share, enhance, and analyze their knowledge of life conditions, to plan and to act" (p. 1437).[29] Likewise, Demodaran[30], Krippendorff[31], and Nieusma[32] review a variety of design approaches that stress the importance of involving stakeholders in the design of solutions. Finally, others argue that participatory approaches that focus on assets, rather than needs, are even more powerful because they provide a positive representations of community[33,34] and rely on capacity building and empowerment of community (as reviewed by Kramer et al.[35]).

Finally, the *failure to apply knowledge* is the most nuanced category of the proposed failure typology. It raises the questions "What do we effectively apply what we learn about a context?" and "How can we base our design choices on the acquired knowledge about a given context?" One possible way to avoid such failures is to create requirements that not only consider what customers or stakeholders request, but extend also to cultural aspects of a community that could affect the design, including the natural, social, and structural assets available in the community.

Then when engineers need to make design decisions, they should consult and consider the extended requirement criteria and verify that the contextual criteria are always met. Many other strategies should be researched and implemented.

The typology proposed in this paper is not comprehensive and we believe that many other types of failure have happened. This study has also been limited by the lack of publicly available stories of failed projects. Hence, we conclude this paper by inviting engineers and engineering students engaged in humanitarian and similar projects to share publicly their failure stories, so that we can all learn from each other and avoid harming the communities we want to serve. We also invite sharing of strategies used successfully to prevent failures from occurring.

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