A Systems Engineering Framework for Small Scale Rural Community Engagement Projects: A Case Study

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Abstract

Small scale rural community engagement projects which are conducted by engineers fail on occasions as a result of a range of factors such as poor management, a lack of monitoring and evaluation and most importantly, not taking into account social elements. A structured approach on conducting small scale rural community engagement projects is hypothesized in this paper as a solution to improve the success of small scale rural community engagement projects. The paper shows the design of a Systems Engineering framework for the conducting of small scale rural community engagement projects, incorporating social elements and verification procedures to assess the strengths and weaknesses of such projects which could assist in ensuring project success. The framework was applied to a case study and validated on an applicable rural community - based project. An impact assessment was conducted and data analyzed statistically, proved the validity of the framework through means of measuring indicators. The impact assessment revealed that further work was required in the area of maintenance and knowledge transfer but was successful in meeting the needs of the community and dealing with social issues while the framework was being applied to the community-based project, Gwakwani.

Keywords
Impact assessment, Small scale rural community engagement projects, Systems Engineering framework, social development

1. Introduction

Community engagement is said to be an effective tool in realising projects that appeal to a specific group of people whom are either affiliated by geographic proximity, special interest or are affected by similar issues affecting the well-being of those people [1]. Through participation with communities, community engagement provides a platform for on-going discussions between community members regarding their concerns. Different groups of people with different cultural backgrounds are provided a chance to feel empowered through integrating knowledge and opinions with each other in order to address a common concern. Research shows that community engagement allows for the creation of local networks of community members as well as external stakeholders through broadening the base of support in order to put various stakeholders in touch with each other [2][3].

Engineers are increasingly being encouraged to serve the public and consider the societal implications of their work [4][5]. However, the standard "hard" engineering approaches to problem-solving frequently ignore the social aspects of engineering as engineers are said to be intensely uncomfortable of undertaking social projects [6][7]. Such processes tend to transfer process control from the engineer to the layperson. Social gaps may have negative effects on this community engagement projects and therefore lead to failure [8]. Not involving communities in project development can have serious long-term negative impacts on a community's economic, environmental and social outcomes [9]. Establishing dialogue and building strong and genuine relationships with local communities and other stakeholders is recognised as a vital part of any project [10]. Incorporating social aspects and community participation into a community engagement project management model may bridge this gap of social inexperience of many engineers and project managers of today.

Social elements that are left out of engineering or management frameworks for projects that rely on community participation, result in the lack of consideration of a number of factors imperative to the success of a community project. Factors such as community participation, a complete set of user requirements, monitoring, evaluation and overall management of a community project. The design of a Systems Engineering based framework for small scale rural community engagement projects is hypothesised to improve the success of community-based projects conducted by engineers as it will include strategies to tackle social elements, contain monitoring and evaluation stages as well as provide a systematic approach to conduct community-based projects, thereby ensuring an ease of management [11].

The remainder of the paper includes a brief background in section 2, a description on the proposed framework in section 3, the implementation of this framework in section 4, the results of the implementation in section 5 and conclusion in section 6.

2. Background

Cultivating engineers into "global engineers" and project managers into "community engagement experts", skills must be transferred within academic institutions from the start of these professional careers so as to prepare them for their broader role in business and social implications [12]. Literature shows that the concept of community engagement is increasing, however, it is still fairly new. Universities that have implemented community engagement activities into curriculums have shown to display highly beneficial results, such as giving students a "hands-on" experience that could further students in career goals, gain a further sense of civic duty and become more connected to the community [13]. Engineers Without Borders (EWB), a Non-Government Organisation (NGO) comprising of mainly engineers have been working since 2008 to revise and develop engineering curricula to integrate community engagement and engineering. The aim of EWB organisation was to improve a student's knowledge and learning outcomes in real world problems, so that when students graduate, there is a realisation of social responsibility in project design and development through engineering work done together with communities to resolve common technical challenges being faced [14]. Initiatives like EWB and many more NGO's are initiated through students whom are willing and have an idea of what this involvement entails. However, the other students may not always be willing- not because there is a lack of interest to engage with communities but rather because students have exams, papers, research, class homework or jobs and may not have the time to volunteer [6].

Businesses promote community engagement activities as it increases the business's exposure and brand awareness [15]. Engineers and project managers in business organisations that require the successful completion of community activities, struggle in this regard as there are additional societal tasks that need to be added into a typical framework of a project. These tasks include community assessment procedures, adequate planning, highly performing management, input from community and the various stakeholders involved and most importantly monitoring and evaluation of the community-based project. These tasks may affect the success of community-based projects conducted by engineers and project managers and is imperative that care be taken in terms of the social aspects [16].

A community engagement framework was designed on the basis of Systems Engineering and Project Management theory. The foundation of the framework was built upon the ISO 15288 System Life Cycle standard [17]. Project management principles were integrated in specific areas of the framework with the core of the framework focusing on the social aspects of a community engagement project. The framework included community assessment procedures, community negotiations, community participation and monitoring and evaluation stages.

2.1 The Case Study: The Gwakwani Project

The village of Gwakwani, a small rural community located in the Limpopo province of South Africa (shown in figure 1), contains 80 to 100 villagers, with the Venda language spoken as the villager's first language. The community can be classified as forming part of the underclass segment of the population, making a living from subsistence farming. The village's current infrastructure mostly consists of mud huts and small brick dwellings, with electrical items being powered by solar technology. Due to the lack of grid connected electricity, villagers provide lighting to the dwellings in the form of candle light or with the use of lead acid batteries to power radios or any small electrical devices. The village relies on financial gain from those whom are either employed in the households, producing an income from the farming, or from the unemployment grants provided by the government.

Figure 1: Geographic location of the Gwakwani village within the Limpopo province of South Africa [Google maps].

A community service project was conducted in 2014 by the University of Johannesburg, tackling the first phase of the "Gwakwani project". The community service conducted in Gwakwani, included the successful implementation of a solar powered borehole pumping system, a cellphone charging station and a monitoring station, all powered by solar technology. The implementation of the various systems in the first phase of the Gwakwani project was done so as to resolve the sustainable water needs of the community, taking into account the financial circumstances of the community.

It was found in the first phase of the Gwakwani project that there was minimal participation of the community, minimal consideration with regard to social elements, a lack of monitoring and evaluation of the systems implemented and lack of structure. Even though the project was a success, there was still room for improvement in the identified problem areas and if community-based projects were to continue being conducted, a more structured approach would be required. The designed framework was to be applied to the Gwakwani village, aiming to resolve a current community challenge being faced.

In 2015, the second phase of the Gwakwani project kicked off under the guidance of the newly developed community engagement framework for small scale rural communities. The project team from the University of Johannesburg consisting of technicians, volunteering students, lecturing and administrative staff with a translator utilized the proposed framework for the execution of the project. To gain a better understanding of community's needs and opinions of villagers regarding concerns of the community, a community assessment was conducted through a series of intensive cultural negotiations between community representatives and the project team leader through a translator. The community assessment included a surveying session with a brief group discussion with the community and a site inspection where possible technical aspects of the community's challenges could be assessed for a possible community engagement project.

Information compiled from the community needs assessment allowed the project team to analyse and discuss critical issues within the village. A decision matrix revealed that a lack of lighting in the village posed the biggest concern to the community. Due to the lack of electricity in the village, community members make use of candle light and fires to provide lighting to dwellings and to cook and bathe, respectively. The lack of lighting in the community revealed itself as the major community challenge being faced by Gwakwani as this prevented school learners in the community from completing any academic activities in the evenings and the community members from performing evening tasks. The villagers claimed that environmental hazards (such as poisonous wildlife and hazardous plants) posed a high safety risk in the evenings for villagers when walking between dwellings. Even though villagers made use of candles to provide lighting in the evenings, this had a financial impact on the community and posed as a high safety risk due to the thatched nature of the dwellings.
Electrical company, Schneider Electric, together with the Electrical Engineering Department of the University of Johannesburg, conducted this community engagement project as Phase II of the Gwakwani project, by utilizing the designed Systems Engineering framework. A monitoring and evaluation process was applied to determine the validity of the framework and the success of the project itself.

3. Framework

3.1 Research Methodology

A framework methodology was used to guide the manner in which this study was conducted. The methodology followed the basic engineering research process [18]. Figure 2 illustrates the steps that were followed for this study.

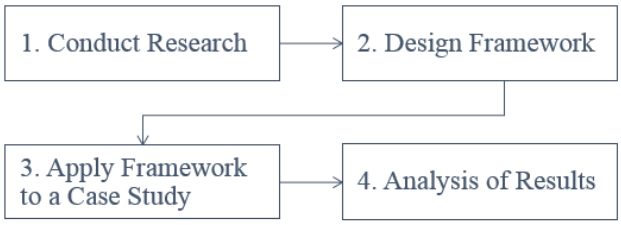

Figure 2: Flow diagram of methodology

Research formed a vital part of this study as it provided the author with a platform on the current state of knowledge within the field to be studied. Step 1 shown in figure 2, "Conduct research" indicates that a thorough literature study was conducted looking at culturally acceptable methods for negotiations, existing community engagement frameworks such as the Alexandria Civic Engagement Framework developed to guide the community of Alexandria, Virgina on conducting civic engagements [19] and similar work in the field was studied. A background study on Systems Engineering theory was examined along with methods on analysing qualitatitive data, in specific Likert scale survey data and Dichotomous survey data.

A detailed study of the ISO 15288 Systems Engineering Life Cycle standard was to be similarly modified and integrated with various management and community processes as part of the framework designed for this study, indicated by step 2, "Design Framework". The framework was to include methods of testing as well as analysis such that the framework could be implemented by individuals in industry or education. A step by step approach was to be included along with implementation and analysis phases.

An application phase within the methodology was to be included where the framework would be tested, indicated by step 3, "Apply Framework to a Case Study". This would not only reveal the capability of the framework and output a conclusive answer to the research but also indicate a precise result on the success of the framework such as strengths and weakness and physically indicate that the framework is successful in being demonstrated. A case study, within a small scale rural community, in this case Gwakwani, was to be used to demonstrate the capability of the framework as well as resolve a "community challenge". The case study allowed the author to gain a clear understanding around the success of the framework, with intention to implement this framework to future community projects as well as make precise deductions on the study itself [20].

An analysis stage in step 4 of the methodology was included, "Analysis of Results". The framework was to be tested based on the case study, using surveying methods, in this case Likert scale and dichotomous data surveying methods were used and used to analyse the data respectively. Community interaction was required for this stage as not only the efficiency of the system was important but also the meeting of the community's requirements. Results found, would enable the researcher to validate the success of the framework and the community project.

3.2 Framework Design

The standard engineering approach to solving design problems is through the use of the well known "Engineering Design Process" [18]. This basic 5 step process, however, can not account for the important aspects within a community project that must be considered during analyis, namely community and cultural negotiations and project selection procedures.

A management framework was designed based on Systems Engineering, Project Management and Community Engagement theory, in order to serve as a guide on how to comduct Community Engagement projects for small scale rural communities. The framework was built upon the core foundation of Sytems Engineering theory using the standard life cycle procedure, namely the SANS 15288 System Life Cycle standard. The standard was adapted and

modified to include community assessment and negotiation procedures in order to account for the social aspects that come with community engagement projects, while maintaining the found relevant processes in the framework, namely design, verification and validation as well as maintenance stages.

The basic structure of the framework comprises of five "phases", namely, a Concept phase, a Detailed phase, an Execution phase, a Monitoring phase and a Maintenance phase. Within each phase of the framework are a number of "steps" and within each step are a number of "tasks". For each phase the inidividual is required to begin with each step and complete the respective tasks within the step and once those taks have been complete, proceed onto the next step. Once each of the steps relevant for that phase are complete one may then proceed onto the next phase, allowing one to transition through the framework. For the purposes of this paper only a short description of the phases and steps will be discussed as opposed to the detailed description of the framework which includes the phase, steps and tasks in terms of hierarchy.

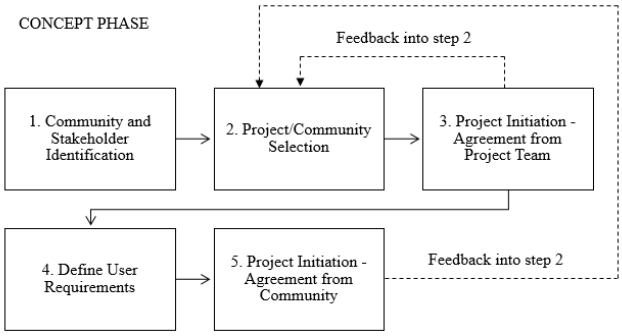

Figure 3: Concept Phase with 5 steps

According to Figure 4, the framework begins with the Concept Phase. Figure 4 shows a flow diagram of steps 1 to 5 which are required to be completed, in order to have completed the Concept Phase, before moving ahead to the Detailed phase. In order to describe the framework it must be noted that the key stakeholders are the community, project team and the supplier. The project team conducts the project and therefore uses the framework as a guide to the project.

Following numerical order, step 1 begins with the identification of the community and other stakeholders involved in the project indicated by the "Community and Stakeholder Identification" step. Step 1 sets a foundation for the project team to indicate requirements before entering into an agreement amongst the team members to engage into the community project. Skills development of project team members, development of future relationships and opportunities to market the project team to the public for purposes of increasing calibre as well as increasing awareness of the team may, may be amongst the list of requirements. Using a "Community Service Project Selection" process from the Michigan State University, for step 2 "Project/Community Selection", allows the project team to make a selection on the community selected for community service [21]. Selecting communities may require personal interaction with the team and the community and is for that reason that this project selection process has been modified with a standard community assessment procedure which will allow the project team to initially meet with various communities for potential community projects and determine the community for community service [22]. The community assessment has been modified to include a step by step approach on how to approach communties, receive permission for entering and speaking with community leaders and proposing the possible partnership to conduct community service. This step by step approach accompanies the existing procedure on how to survey a community.

Still in step 2, once the project team and the community have been "engaged", the project team may have the opportunity to survey community members based on the "community assessment" procedure and obtain opinions from community members on "challenges" being faced as well as future plans. Challenges in this case, refer to tasks that are daily completed by the community with difficulty. The community assessment procedure provides information on compiling a survey and analysing the information found. Proceeding to step 3, "Project Initation-Agreement from project team", the project team assesses the information found using a "Community Project

Selection" criteria from the Univeristy of Princeton, which examines each challenge faced by the community in terms of factors such as what benefits will be claimed for the community and project team from resolving the various challenges, money and hours spent per individual and the percentages of involvement time to the project team [23]. The project team uses the opportunity to discuss each community challenge being faced for the respective communities and examines how solving the chosen community challenge will allow the for the objectives of the project team to be met. The team will also use concerns raised by community members in the community surveys to make the final decision. Once a consens is achieved then the project team enters into an agreement amongst each other on the chosen community and community challenge being faced by that respective community.

Step 4, "Define User Requirements", entails the project team surveying the selected community, repeating the community assessement procedure but instead of surveying the community, the project team examines the selected community challenge from a technical perspective. Factors examined would be the existing infrastructure of the community, feasibility of implementing possible solutions, current alternative methods being used to counteract current the challenge being faced and physical boundaries. This information would be used to draft a list of "User Requirements", used to address the community in the next step and to determine an optimal solution.

Proceeding to step 5, "Project Initiation – Agreement from community", the final step to the Concept Phase, entails an agreement process between the project team and community leaders. The project team would use this meeting as a platform to address findings from the community assessments conducted in steps 2 and 4. The project team would describe opinions and concerns by community members as well as technical findings, identified by survey results. This meeting will also provide the community with an opportunity to address any concerns and queries with regard to the findings and the proposal for community service. Once the project team and community enter into an agreement for the project team to conduct service in the community, this will mark the completion of the Concept Phase. Steps 3 and 5 of the Concept Phase, are both agreement steps and include feedback loops into step 2. For step 3, if the project team is indecisive of a community to select as well as a community challenge to tackle, then the project team will return to step 2, where another community and community challenge will be identified. For step 5, if the community and project team do not enter into an agreement, then the project team will have to return to step 2 as well.

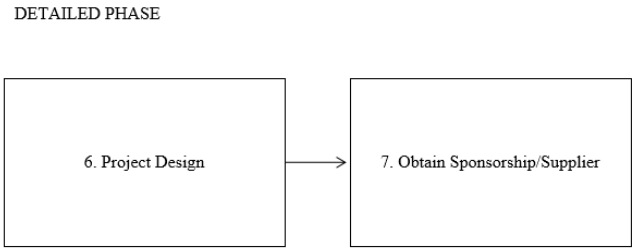

Figure 4: Steps 6 and 7 of the Detailed Phase

Figure 5 illustrates steps 6 and 7 in the Detailed Phase, "Project Design" and "Obtain Sponsorship/Supplier". The Project Design step includes the design of potential solutions to the community challenge as well as the analysis of the solutions using an advantages and disadvantages analysis. Factors considered are cost to purchase and operate system, assembly of system, safety and performance. A final decision on the solution is made using a point system generated from a decision matrix. Upon making this decision the community is informed and given the opportunity to add input to the chosen solution. As part of the design a maintenance strategy is also defined. The framework was designed to obtain funding for community projects from donors and sponsorships. This is to to not only assist the project team financially but to also build relationships between stakeholders. Step 7 includes a strategy on obtaining a sponsorship and engaging into an agreement with a possible supplier. The strategy looks at requirements to generate a compelling sponsorship proposal and conducting a meeing with the potential sponsor [24]. Sponsorships obtained may be in the form of materials, finance or support. Once steps 6 and 7 are complete, the Detailed Phase can be marked as completed.

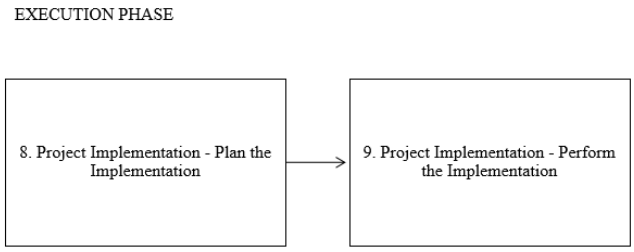

Figure 5: Steps 8 and 9 in the Execution Phase

With an optimal solution in place, the Execution Phase shown in Figure 6, may commence. Steps 8 and 9 comprise of the Execution Phase, which entail implementing the chosen solution in the Detailed Phase. Implementation is made up of planning the implementation and physically conducting the implementation. Step 8, "Project Implementation – Plan the Implementation", describes project objectives and how to achieve it in the implementation. The project team will define a project scope of the implementation period with a Work Breakdown Structure, showing the work done by each member of the team. A Responsibility Assignment Matrix is generated showing the tasks that each team member is responsible for and a Statement Of Work for the implementation period. Network diagrams comprise of the tools to be used during this step in order to examine work allocated for the time period and the slack that would be available using a critical path analysis. Planning will include the logistics required by the project team to acquire materials, the funding required to conduct the implementation and also account for the participation by suppliers.

Once the project plans are developed, authorisation of the community must be obtained by project team to receive permission to conduct work in the community. Plans must be communicated to the community as well as members entering the community. The community may use this opportunity to address concerns and communicate requests to the project team.

Step 9, "Project Implementation – Perform the Implementation", entails the execution of the project plans from step 8. The implementation is to be executed according to the time according with the resources planned for in step 8. The crucial factor in this step is conducting the implementation in a culturally acceptable manner so as to respect the community and complete tasks that were planned for in the projet plans. Introductions to the community is to be done during the intial time period of the implementation in order to establish a comfortable relationship between stakeholders. Implementation plans must be discussed with community members before the implementation takes place and allowing concerns and questions to be addressed by community members should be encouraged. This will motivate the community to not only feel involved in the implementation but to also involve themselves during the implementation. Once the implementation has been completed, the solution must be tested before the team departs to ensure systems are fully operational and use the opportunity to explain the risks involved in operation and maintenance and the operation itself. This will mark the end of the Execution Phase.

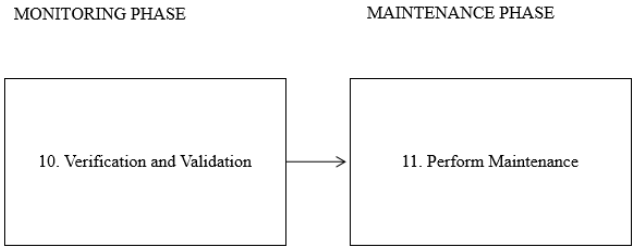

Figure 6: Step 10 for the Monitoring Phase and Step 11 for the Maintenance Phase

After the Execution Phase, the Monitoring Phase and Maintenance Phases are to occur respectively, shown in Figure 7. The Monitoring Phase comprises of step 10, "Verification and Validation", which includes a technique on verifying the system solution and determining whether the system has met the objectives of the community. The verification strategy includes the surveying of community members and doing this using a structured questionnaire.

Step 10 includes methods on designing a questionnaire for the community in order to obtain the required output. The community is to be surveyed based on the questionnaire and the data analysed thereafter [25]. The survey should examine aspects such as system performance, community satisfaction and community/social aspects. The analysed data will be used to verify the success of the community project and determine overall success of the framework. If the results output indicate a dissatisfaction of community members then the project team will be required to return to the community and rectify problems identified. The completion of step 10 concludes the Monitoring Phase.

The final phase of the framework is the Maintenance Phase, which comprises of the final step, step 11. Step 11, "Perform Maintenance", includes the implementation of the maintenance strategies made in step 6 of the Detailed Phase. It is important to take social issues into account in this step as it will require frequent contact with the community to maintain systems as per maintenance schedules. Maintenance should not only include maintenance strategies on improving reliability on systems but rather provide the community with basic training on how to maintain the systems as well.

4. Framework Implementation

Within the Concept Phase of the framework as discussed within the description of the case study, a community assessment was conducted in order to identify a community challenge, which in this case was the lighting issue. Assessing this issue showed that solving it would be optimal in a sense that it is not only a commonly great concern amongst villagers but also may meet the requirements of the project team if solved. Requirements such as skills development, marketing and developing relationships with stakeholders. A second community survey was conducted with a more defined area allowing the project team to assess specific aspects in connection with the lighting issue identified. The team would assess the community from a technical perspective assessing current infrastructure as well as communicating with villagers on possible solutions. This assessment allowed for a set of user requirements to be defined, covering functional requirements and functional boundaries. This information would allow for an appropriate solution to be developed.

As part of the Concept Phase, "Project Initiation – Agreement from Community", step 5, the project team engaged with the community, addressed community assessment results and proposed this as a possible community engagement project. Survey results presented, provided the community with information on major problems as well as a platform to address any concerns and special requests from the villagers. It also provided a purposeful opportunity for community leaders to engage with the project team to work collaboratively in developing an effective solution. With an agreement of the community with the project team to conduct the community-based project, a solution was selected and designed in the Detailed Phase, using a pro's and con's analysis on a range of solutions and a solution determined using a point system within a decision matrix. The decision to install solar home lighting units provided by Schneider Electric, was chosen as the optimal solution in this case as it is compact, safe, easy to install, affordable, contains a back-up unit, there are no operational costs associated and has a history of success in its use. Using the strategy on how to obtain a sponsor for the units in step 7 of the Detailed Phase, Schneider Electric, was approached by the project team for a partnership in the project to assist in the sponsorship of these units to the community.

Together with an agreement of the community for the chosen solution as well as the partnership with an external industrial stakeholder, the Execution Phase commenced with project planning and project execution. Planning the implementation, in step 8 of the Execution Phase, comprised of project management processes such as work breakdown procedures, network diagrams and a general scope of work for each day. These plans included tasks required for each team member with the translator playing a major role in efficient communication between the team and the community. The industrial partner was also encouraged to partake in the implementation through direct involvement in develop and maintain a good relationship with all stakeholders. The industrial partner was included in the project plan for the handing over of donations, the individual home solar lighting units as well as portable handheld lighting units. The implementation was to be conducted over a period of 5 days, where 2 days would be required for transportation to the site and the remaining 3 days for the implementation.

The first day of the installation included introductions of the entire project team to the community and a general information session on the plans over the implementation period, communicated through the translator who played a major role in general communication throughout the implementation. The project team then began the installation of the solar units in the respective dwellings as per implementation plan. The lighting unit consisted of a 12 V battery,

a switch, a 3 A solar charge controller (with a trickle charge mechanism), which included a USB charging output. The system include a 5 W LED lamp, which is able to to last 8 to 15 hours when powered from the external battery. Each household was equipped with 2 lamps [26]. The system was powered from a 10 W solar panel, mounted on a steel mast and erected, north facing outside the each dwelling. An example of the installed system is shown in Figure 10.

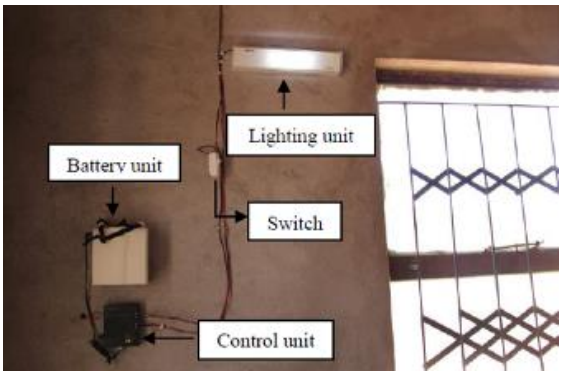

Figure 7: Installed systems in each dwelling

The second day of installation, included an introduction of industrial partner's team to the community and a welcoming event to the supplier by the community as a form of gratitude. The industry partner handed over donations to community members as well as the individual handheld portable lighting units. The industrial partner trained community members on the use of the lighting units and individually engaged with community members. The remaining parts of the day included the installation of the units within the dwellings in the community.

The third day included the final installation of the remaining units and for the testing of the units after sunset at 18:00 pm to verify full functionality. The team tested all units, deterrmining full functionality and the resepective household members could confirm the functionality of the installation, after which all the units were deemed fully functional and were regarded as system healthy. The Project Team concluded the implementation phase with the community with a farewell, through the translator and retuned back to the University. The Monitoring Phase included the verification of the system solution and in turn a validation on the proposed framework. Verification of the system was conducted through a survey analysis to the community, assessing factors such as 'customer satisfaction', 'system technical evaluation', 'maintenance and knowledge transfer' and 'installation process and social evaluation'.

5. Framework Validation

The Monitoring Phase comprised of "verification and validation" stages. The verification and validation strategy has been integrated into the framework to test the success of the implemented system which in turn may be able to deduce the success of the framework. The strategy suggested for the verification and validation stages was to survey the community after project completion. The responses of the community allowed the project team to gain a better understanding of not only the system functionality but rather how beneficial and satisfied the community was with the installed solution. A survey structured for the community, consisted of a variety of 19 questions, assessing customer satisfaction, technical capability, maintenance, a rating on the knowledge transferred, satisfaction on the maintenance schemes as well as the how social activities were conducted.

The questions were posed to the community and the results recorded and analysed. The questions posed were categorized in terms of 11 Likert scale and 8 Dichotomous questions (shown in Tables 1 and 2) which were ideal for analyzing the qualitative data [27]. The survey questionnaire was verified by the project team based on the outcomes that can be deduced and was sent through to an ethics committee for ethical approval. The project team returned back to the community to conduct the survey under permission of each person being interviewed and the data analysed thereafter. The survey was categorized into the following indicators: technical evaluation; installation process and social issues; maintenance and knowledge transfer and customer satisfaction. The survey was answered by 15 individuals of the community. The questions were answered from a numerical scale with a range of 1 to 5, from 'strongly agree' which equates to 1 to 'strongly disagree' equating to 5. Due to the ordinal nature of the data,

the modes and medians of the various categories were calculated. Table 2 shows the data corresponding to questions for the Dichotomous questions, where answers were given in the form of a "yes" and "no".

Table 1: List of Likert scale questions posed to community

Likert Scale Questions	
1	I am satisfied with the lighting system
2	My expectations were met by the system that was installed
3	Since the installation of the system, there has been no technical issues affecting the system
4	The system works well during rainy days
5	I am satisfied with the meetings and discussions with the university before the system was installed
6	The project team was easy to communicate with during installation
7	I was satisfied with the individuals who entered my property for the installation
8	I was properly informed about the intentions from the project team before the system was implemented
9	I was properly informed on how to operate the system when the project team left
10	If something went wrong with the system I knew what to do and who to contact
11	I understood the safety risks of using this system

Table 2: Dichotomous questions posed to community

Dichotomous Questions	
1	Was the installation apart of the plans for the community?
2	Would you be happy for further projects to be undertaken in your community?
3	Do the lights stay on for long enough in the nights?
4	Were you involved in the implementation?
5	Were you satisfied with the method of the installation?
6	Were you satisfied with the duration of the installation?
7	Did you feel properly informed about the visits prior to them happening?
8	Are you comfortable with being able to operate the system once the project team left?

5.1 Gwakwani Survey Results

Questions listed in the Likert scale questionnaire were structured such that the responses "Strongly Agree" and "Agree" would yield in a positive response and vice versa for "disagree" and "strongly disagree". Questions listed for Dichotomous questionnaire were structured such that the response "yes" would yield in a positive response and vice versa for "no". Figures 12 and 13 were plotted from the results obtained from the Likert scale and dichotomous questionnaires.

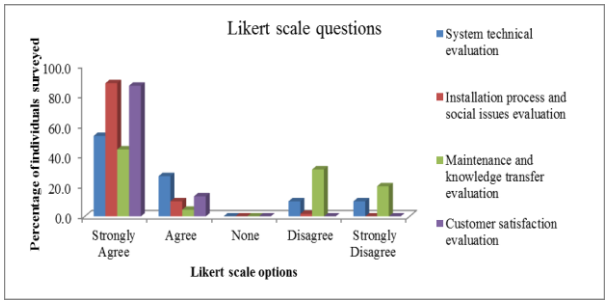

Figure 8: Responses to Likert scale questions.

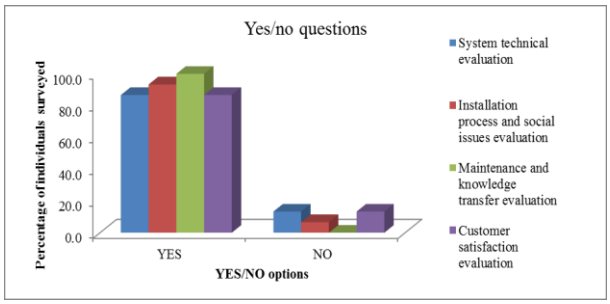

Figure 9: Responses to Dichotomous questions

Figures 12 and 13 indicate the strongest performing category was the "customer satisfaction" category. The community satisfaction indicator tested the personal satisfaction of each community member together with the system solution and whether the needs of the community members were met. Results displayed showed that the community was satisfied with the system itself and satisfied with the project process as a whole. Results also show that positive relationships were developed and the designed system was in-line with the plans of the community. The

second strongest indicator was the "installation and social issues". This indicator looked at the method of installation and the manner in which social activities were conducted, such as community meetings and negotiations. The community was satisfied with the method of installation from the planning to the performing of the implementation. The community also expressed satisfaction in the manner in which community issues were dealt with, from the engaging with cultural customs to the community being informed of each stage of the project within the project process. The negative result in this indicator was that one of the community members felt uninformed of intentions of the project and this may have been attributed to perhaps the absence of the community member during the implementation phase or the community member may have been new to the village.

The third strongest indicator was the "system technical evaluation". This indicator assessed the technical performance of the system. The community expressed that since the installation there had been no technical issues however, the community felt the system did not function any time after 23h00 if used from 18h00 the same evening. Results found here could be attributed to poor communication from the project team to the community in stating that the system was not capable of providing continuous electricity due to the system's specifications and that the back-up unit can only last for a few hours. The system had been designed to use solar energy during the day and the battery back-up unit in the evening. The weakest category was the "Maintenance and knowledge transfer category". This indicator revealed the community lacked the knowledge of whom to contact in the cases of technical issues, how to maintain the system itself and were not aware of the safety risks associated with the system. The community lacking knowledge regarding maintenance was attributed to an insufficient knowledge transfer from the project team to the community, which may have been due to the lack of multiple translators for communicating to each household, during the short duration of the implementation and that this was not accounted for during planning.

6. Conclusion

The developed framework aimed to aid in developing solutions to solve social issues between engineers and communities and in so doing achieve project success. A Systems Engineering framework was designed to ensure the social requirements were met during a typical small scale community engagement project (approached by engineers) and at the same time integrating the necessary stages of the engineering project life cycle. Together with the implementation of the framework into the community and a verification and validation stage of the case study, an accurate solution could be deduced. The framework covered a number of community engagements which allowed the project team to continuously interact with the community, encouraging the community to be a part of the development. The framework incorporated a standard technology design methodology but included a number of community processes. Social processes allowed the project team to feel a sense of responsibility and gain a better understanding of the community's needs and the future plans intended. The work presented shows the design and implementation of a community engagement framework capable of increasing the chances of project success for engineers conducting community engagement projects, through the integration of multiple social processes into a common engineering life cycle process. Based on the findings from the case study, a number of recommendations could be made namely, project teams can conduct thorough community assessments in order to determine accurate user requirements and to also inform the community around maintenance and safety of the systems installed.

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