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Optimal Rural Clinic Location Determination using Scientific Modelling

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Abstract: Rural communities are to a larger extent marginalised resulting in huge populations migrating to urban areas. This study looked at the poor rural people of Vezubuhle with their struggle of poor healthcare facilities. The region has three sections with two clinics situated in sections with the least population. How that decision on the two clinics was reached has no scientific basis as section with the largest population has none. A mixed research method was followed and scientific modelling based on statistical and artificial intelligence methods used. This resulted in an innovative software solution developed giving optimal results free of bias, corruption, or favouritism that can be adopted to any other environment (s) with easy. Authorities in position of power are therefore, advised to embrace use of technology, not only does it bring about efficiency, it can be a huge driving force in attracting investments for the development of rural areas. There must also be community involvement if any project affecting its livelihoodis to be a success.

INTRODUCTION

Urbanisation has seen huge population volumes flocking into cities[1, 2]. This movement for better livelihoods in the cities world wide has also brought with it challenges like access to housing, water and healthcare to local governments[2]. However, there are those who choose to remain in the rural areas for one reason or another; some of which are lack of proper skills for employment and lack of education[3-5]. The rural population is often neglected when it comes to provision of basic services like water and healthcare by the local and provincial authorities[6-10].

Vezubuhle situated in a rural area of Mpumalanga is a reference point in this study. It is not considered a disctrict but is made up of three sections under the leadership of a traditional chief with councilors elected along party politics. There are only two clinics in the whole region and a mobile clinic which comes around regurlary on a particular day of the week. In addition, there are primary and secondary schools and some farming activities taking place. Vezubuhle's roads are still gravel and there is a lack of public transport (buses) but few taxis are available for the public to use. Not all areas in the sections have electricity and running water.

Basic services like healthcare, access to water, education and subsistant farming are not enjoyedin the rural areas. However, as much as government is trying to address the issues of these basic needs in rural areas, there seems to be challenges with implementation by the local governments. Poor rural schools are under resourced and

water supply as well as proper sanitation not provided[11]. It is important to provide people with easy access to healthcare services. Unfair practices in the selection process is very common, it be in business, academia or political circles with best candidate often sidelined for a particular job. This unfairness in the selection process where a weak candidate is chosen can be deliberate or random with no scientific methods applied to collaborate or justify the process even if such process is repeated several times. Therefore, samples of unfair selections are not representative of the population to be analysed and result in sample bias with optimal solution never achieved[12]. According to the Council for Scientific and Industrial Research (CSIR) guidelines, the construction for a healthcare facility in a rural area should be at a site which can cater for ninety percent of the population within five kilometer radius. Based on the CSIR gudelines, the study intended to establish whether the contruction of the two existing clinics in Vezubuhle was an optimal solution.

A similar study carried out in rural province of KwaZulu Natal only considered the population based on the number of houses in that mapusing Geographical Information System (GIS)[13]. This might not give a clear indication on the actual population as it is common for an individual to have a house in the rural area but be living in an urban area most of the time due to employment and not depend on the healthcare facility there. A study done in Nigeria established that people living close to a healthcare facility have better quality of health than those who live far[14]. It has also been established that people living far from a primary healthcare facility have a higher degree of depression[15]. It is well documented that people working on farms often get sick from chemicals used, equipment used as well as the environment they are exposed to as such would require visiting healthcare facility for treatment[15].

Rural development in developing countries is often affected by poor decisions made by the authorities, lack of expertise, lack of funding for such projects, not involving the communities[6-10, 16] and incorrect data about the differrent rural areas and their capabilities[17].

It is therefore, based on these evidence that this study was carried out to determine the optimal solution in deciding where to construct a healthcare facility or healthcare facilities in Vezubuhle considering the actual current population and any other activities prevailing in the region. This study looked at these different activities (farming, schooling, water supply and existency of clinic) in relation to the population. Statistical method showing unfairness or probability of misclassification in selection processes was considered[18] and artificial intelligence modeling taking into account the required constraints or requirements used to come up with an optimal solution which is fast, fair and reliable[19].

MATERIALS AND METHODS

Residence of Vezubuhle were used in this study. A questionnaire was prepared with both quantitative and qualitative methods included. Use of the mixed method was done specifically to offset any in consitencies that could arise from either method. Copies of the questionaire were distributed using purposeful sampling method targeting adults, school principals and farm workers from the three sections of Vezubuhle. A total of seventy-five copies of the questionnaire were distributed to the three sections. In addition, an interveiw was carried out with the elected councilor of the three sections.

Probability of misclassification in selection problems often results in poor decision making. To illustrate this important concept, assume that the selection process starts with k competitors (different populations of the three sections) and that those qualifying get placed in section based on merit with those failing to meet the cut going in section j. Section j will therefore, consist of all those who failed to meet the minimum requirements for selection. By definition, probability of misclassification is the probability of selecting a competitor to the section i when he/she should be classified in j denoted as p_{ij}[20]. Particularly, the probability of correct selection for section i is p_{ij} and probability of misclassification is $1-p_{ij}$ for i = 1, 2, 3, ..., k. Now, Total Probability of Misclassification (TPM) is given by:

- TPM = P (misclassifying i candidate OR misclassifying j candidate)
- P (candidate quilifies to be in i and is misclassified)+
- P(candidate should go in j and is misclassified)

$$P(X \in i)P(X \in j \mid X \in i)+P(X \in j)P(X \in i \mid X \in i)$$

The calculation of the method discussed above was incorporated in the software solution developed using Artificial Intelligence (AI) modelling. The use of AI in problem solving has advantages which include: ability to solve complex problems giving reliable and efficient solutions in a fast way and the ability to eradicate any errors or favouritism in decision making. The solution considered the set of variables given the domains which existed and the constraints to be satisfied during the mapping of the variables to the domain relationships[21]. To illustrate these concepts as they applied in this study: set of variables were the populations of the three sections in Vezubuhle given by $X = \{s_1, s_2, s_3\}$ set of domains given by D = {PHC, PHCM, DRH, MC} where, PHC = Primary health clinic, PHCM = Primary Health Clinic with Maternity, DRH = District Referral Hospital and MC = Mobile Clinic with one domain value for each variable and set of

Table 1: Summary of activities

Section	Population	Farming activities	Number of schools	Water (boreholes/dams)	Clinics
1	10 399	5	3	4	0
2	1 500	1	1	1	1
3	4 459	3	2	1	1

constraints given by C specifying the pairwise relation between X and D population sizes based on CSIR guidelines.

RESULTS AND DISCUSSION

Quantitave method

Interview: Results of the interview carried out with the councilor gave the actual data for the three sections as shown in Table 1.

For each section in Vezubuhle, the data provided was the population, farming activities (small to medium resulting in the ability to sell such products), total number of schools (primary and secondary), reliable water sources supplying the community and the number of clinics in that particular section. Based on Table 1, the total population of Vezubuhle adds up to 16,358.

Clearly, section 1 with the largest population and most schools as well as farming activities has no clinic to provide healthcare services to that population while sections 2 and 3 with far less population figures and activities have each a clinic which supports the probability of misclassification. Usually, rural settlements are dominantly found in areas close to sources of water, it be for drinking and cooking, cattle, and agricultural activities which is the case with section 1. Therefore, the decision to have clinics in sections 2 and 3 defies logic.

Software solution: The data obtained from the councilor was then used to develop a software solution using the constraints or requirements as specified in the CSIR guidelines of 2012. These guidelines state the facilities which must exist for the different population sizes ranging from urban to rural villages in the country. Figure 1 shows the results of the software solution as derived from the use of python programming langauge.

The software solution shows the exact results which were accurately determined and reliable to use. The results show that sections 2 and 3 are classified as remote villages as the population of each falls in the range 500-5,000 people while section 1 is classified as a village with population ranging between 5,000-25,000 people. In addition, section 1 qualifies to have a primary healthcare clinic without maternity capabilities built in a central location on a 0.2-1.0 ha size land able to serve 90% of the population within a 5 km radius. The facility also should have a permanent primary healthcare nurse with additional support staff and a doctor visiting the clinic on a regular basis.

It is clear that section 1 which was supposed to have been chosen to have a clinic was misclassfied but that situation was rectified by the software model. Sections 2 and 3 classified as remote villages do not qualify to have a clinic but instead qualify to have a mobile clinic which would visit the sections regularly. Indeed this shows poor decision making by the authorities and a waste of resources which under normal functional systems are under utilised.

Qualitative method: One set of questionnaire was distributed to the different communities including school principals and results received and analysed.

Forty three responses were received of the possible seventy five copies of the distributed questionnaire. This constitutes 57% respondents who participated in the study. The results show that 58% of the respondents were women. The fact that there were more women participating in the study came as no surprise as in most cases women remain in the rural areas while men migrate to urban areas for employment purposes.

Easy access to the clinic: On the question whether it was easy to get to the clinic, most respondents (92%) disagreed. They stated that the roads were very bad with little regular maintenance done on them. The 74% of the school principals also added their voice by stating that the clinics that existed in the area were not easily accessible creating a major challenge for their learners and staff. 70% of the respondents from the farming community stated that it was very difficult to get to the clinics if injured while at work as they were too far. It would suggest that majority of those who disagreed on the accessibility of the clinic where people from section 1 where there is no clinic at all.

Time to reach clinic by walking: On the question of how long it took one to get to the clinic by walking, only 12% stated that it took them 20-30 min while 13% stated that it took them at least 5 h to get to the clinic which would suggest that these are the people from section 1 without a clinic and with the largest population. Figure 2 shows the time ranges from 30 min to 5 h.

Clearly, location of the clinics seem to be far from the people they are meant to serve as majority of the people have to spent long hours walking to get healthcare services.

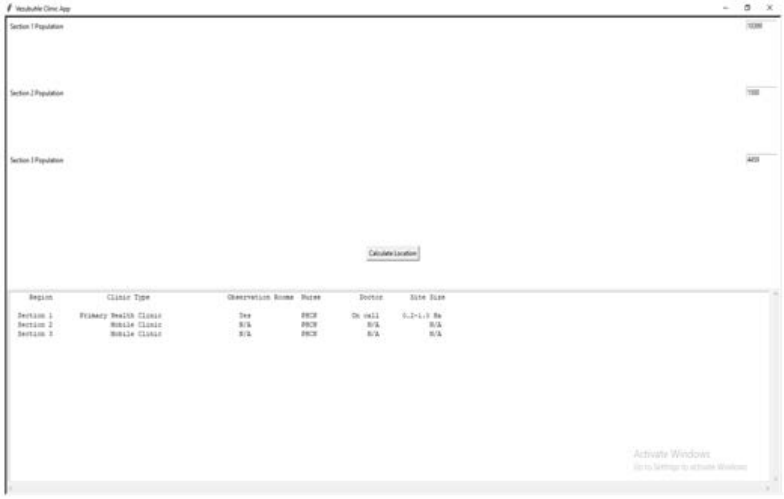

Fig. 1: Software solution results

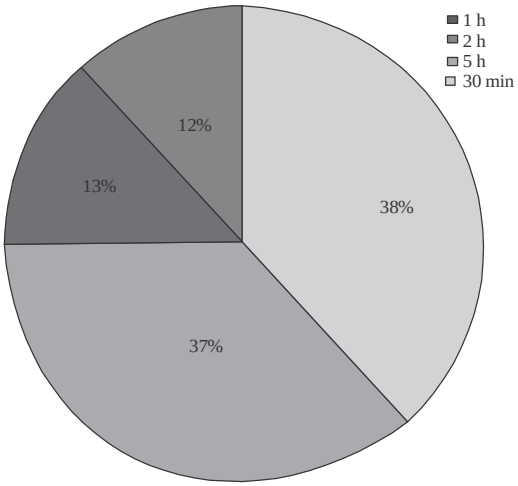

Fig. 2: Time to reach clinic by walking

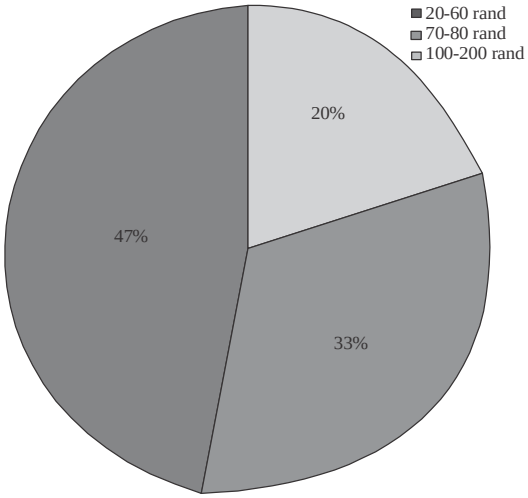

Fig. 3: Cost using public transport

Time to reach clinic using private versus public transport: On the question of what it would take one to get to the clinic using private versus public transport, respondents stated that it can take one anything from 30 min to 2 h to get to the clinic if they make use of the public transport while it could take 5-30 min for those using private cars.

Again a time of 2 h to get to the clinic using public transport shows that these healthcare facilities are too far from most of the people and would also suggest that the road infrastructure is very bad.

Cost using public transport: On the question of what it costs to travel to the clinic by public transport, majority of the respondents stated a fare in the range of 100-200 rands with the least cost ranging from 20-60 rands. Figure 3 below illustrates the different senarios.

From Fig. 3 above, 20% of the people paid the least on public transport to get to the clinic which would suggest that these are the people living closer to either of the existing clinics. It would further suggests that the 47% of the respondents encurring such high transport costs are those living in section 1 far from either clinic. Poor road infrastructure might also play a major role with regard to the high transport costs.

Patient waiting period: On the question of how long it would take before one is attended to by the healthcare official, majority of the respondents (48%), stated a minimum waiting period of at least 2-3 h. About 8% of the respondents stated that it could take 6-8 h of waiting before receiving any form of care. Figure 4 illustrates the patient waiting time in hours.

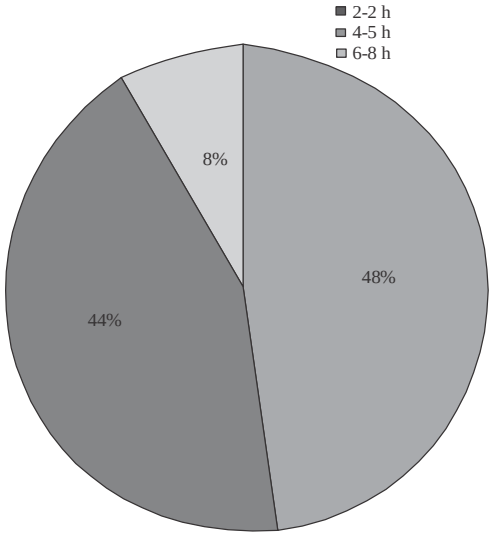

Fig. 4: Patient waiting time

Clearly, the waiting time by a patient before receiving care indicates that there are major problems with the staff at these healthcare facilities. These are the very patients who walk long distances to be at the clinic and must then walk back after being attended to which suggests they leave their homes very early before sun rise with greater chances of travelling on empty stomachs. It is not clear though why the small percentage of respondents would have to wait up to 8 h before being attended to. Either the staff just do not care about the patients or feel they are doing them a faovour.

Medication supplies: On the question of whether there was enough supply of medication at the facilities, 86% of the respondents stated that there was not enough supply. Maybe this would suggest the poor service provided to the patients but still if that was the case, one would expect quicker service instead of allowing people to wait for such long hours to be told there is no medicine.

Staff skills: With regard to the question on skills set of the healthcare workers, 89% of the respondents felt the nurse at each of the two clinics did not have the right skills of caring for the sick and was rude to the patients. This is what some had to say:

"The nurse at the clinic is never on time to open the clinic and start attending to patients. She would arrive and find long queue of patients sitting outside", "Even if she lives at the clinic within a stone through, she is never on time", "We are afraid to complain to her or ask her why she is not opening the clinic for fear of victimisation". This suggests that there is no accountability on the part of authorities, there might be no regular check ups on the staff or there is no unplanned visits to these rural clinics, so, healthcare workers do as they please. This would correlate well with the amount of waiting time patients experience at these facilities.

Improvement of healthcare services: On the question of how healthcare services could be improved, this is what some had to say:

- "More nurses should be hired so that people do not have to wait for a long time in queues"
- "Roads in the area must be constructed and maintained all the time"
- "Mobile clinics must be organised and be available 5 days per week and operated for 24 h"
- "The authorities must build a clinic in section 1 of Vezubuhle in a central place like where they bring mobile clinic occassionally, so that, everybody can easily walk to the place without difficulties of distance or transport charges"

It would seem patients prefer mobile clinic which often comes to the area. The preference might be because the mobile clinic has adequate medical supplies and renders better service than the two clinics. Without proper road infrastructure it makes it impossible to even attract professionals with correct skills to work in the area as well as attracting investments. Suggestion on where people would like to see the clinic built correlates very well with what the software solution produced that it be built in section 1 of Vezubuhle in a central place for easy access by majority of the population. Effective rural development planning has several benefits, some of which are:

- Reduction in urban migration
- Attraction of skilled professionals to work there knowing their children will be able to go to good schools and access to better resourced healthcare facilities
- Attraction of investors and
- Improvement in the quality of life

The mixed method applied in this study did meet the objective set out which was to come up with an optimal solution in the determination of the location and type of healthcare facility for the population of Vezubuhle. Poor decision making not made on any scientific basis was well exposed. This was made possible by applying statistical and AI methods through a software solution which considered all the variables, domain and constraints to be met. The use of actual population figures as provided through the interview with the councillor assisted hugely in determining the optimal solution which in our view

addresses the shortcomings of reliance on GIS which was used in rural KZN province. Though the study was only limited to one section of the municipality, the same method can be extended to cover the whole municipality, province or nationwide as the software solution is adaptable to the different variables, domain and constraints that would exist in those environments. Furthermore, the study did not establish whether those people living closer to the clinic were healthier than those living far. A study on that aspect could be included when the study is carried out on a larger scale to include the whole province. In addition to the limitations, the researchers failed to note the number of returned responses from each section of the village to make it easier to determine the percentage of respondents from either section.

CONCLUSION

Scientific methods and use of technology in particular in solving complex problems must be embraced. It is therefore, critical that authorities tasked with rural development planning adopt innovative software solution to improve decision making so as to eradicate corruption and favouritism. Many projects in rural developments fail because those in power never involve the communities. It is therefore, imperative that those in position of power consult the people, so that, there is buy-in as such practice cultivates a sense of ownership within that community.

SIMPLE SUMMARY

The rural community of Vezubuhle in Mphumalanga province of South Africa under the leadership of a chief and an elected councilor struggle with the provision of quality healthcare. The region has a population of over 16,000 people and has only two poorly re-sourced clinics located in sections with least population figures. Nobody knows how the decision to build these two clinics in these sections was based on. Clearly, there was no scientific proof on the decision making process. A mixed research method was followed and scientific modelling based on statistical and artificial intelligence methods used. This resulted in an innovative software solution developed giving optimal results free of bias, corruption or favouritism that can be adopted to any other environment(s) with easy. Authorities in position of power are therefore, advised to embrace use of technology. Technology brings about efficiency and can be a huge driving force in attracting investments for the development of rural areas. Furthermore, authorities must involve the local community if any project affecting its livelihood is to be a success.

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