Maximum covering location problem to select facility location for operation timbang in the City of Iloilo, Philippines

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1. INTRODUCTION

Nutrition is a vital aspect of health and development. Good nutrition is always related to enhancing all stages of health, more strong systems, better childbirth, a lower risk of noncommunicable diseases, and increased longevity. Malnutrition, including underweight/severely underweight and overweight/obesity, is a global problem, especially in third-world nations. Malnutrition presents significant threats to human health [1]. Non-governmental organizations and government entities collaborate provide the scientific guidance

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and decision-making tools that can assist nations in establishing their own programs and taking action against all types of malnutrition [2].

In the Philippines, there are three primary nutrition and growth assessment programs for children aged 0 to 71 months. These include a) the National Nutrition Survey of the Department of Science and Technology (DOST), b) the health centre- or facility-based growth measurement and advertisement services provided by the healthcare workers, and c) Operation Timbang Plus or OPT Plus, which is conducted in the barangays every first quarter of the year. The barangay is the smallest administrative unit in the Philippines. These programs provide the Nutrition Council of the Philippines and the Local Government Units with critical information on the nutrition status of the population for use in planning nutrition programs, formulating nutrition policies, and monitoring child and total nutrition [3].

Operation Timbang (OPT) Plus is one of the Philippines’ programs that focuses on nutrition by conducting an annual assessment for 0-59 months old children in barangays to identify the malnutrition data in the area. Fig. 1 shows the mechanics and process of OPT Plus. It is the overall scope of the process of OPT Plus Program [3]. These are utilized in action planning, specifically for estimating the number of malnourished individuals and determining which community members would receive priority services. These data can offer government agencies with an overview of the nutritional status of the population and insight into the efficacy of the local nutrition program. OPT Plus's primary purpose is to collect data for nutritional monitoring and evaluation of local nutrition initiatives [4]. In particular, as outlined by the National Nutrition Council, it strives to:

1. Identify households with children who are below or above average weight;
2. Identify and assess children with below and above average weights who require assistance;
3. Detect infant and kid development delay as soon as feasible;
4. Encourage parents to get their children frequently weighed;
5. Determine locations and individuals with top priority for local government feeding programs;
6. Provide nutrition and health services/projects to youngsters with below-average weights; and
7. Evaluate the performance of the local nutrition program.

The evaluation team consists of the Rural Health Midwife, the BNS and other Barangay Council members, the BHWs, and the Day Care Worker (DCW). Weighing and measuring height are surveyed when and where it is convenient: in a barangay hall or daycare centre of each barangays [4].

The Iloilo City Health Office of the City of Iloilo is responsible for conducting the OPT Plus in Iloilo City, Philippines. Last 2021, the office also completed its OPT Plus program last. They collected 35,778 respondents aged 0-59 months old children from the seven districts of Iloilo City: City Proper, Molo, Arevalo, Lapaz, Lapuz, Jaro, and Mandurriao. The data from identified and quantified preschool children classified as underweight, severely underweight, overweight, stunted, severely stunted, tall, wasted, severely wasted, and obese. The next objective is determining priority areas and individuals for program planning purposes. A community centre is established to cater to the identified underweight and severely underweight, and a playground for the overweight and obese [5].

Numerous studies have been proposed by using different types of models to optimally solve facility location problems [6]-[8], especially in the field of healthcare facilities [9]. Tirkolaee et al. [10] Designing a closed-loop face mask supply chain during the COVID-19 pandemic. Aghighi et al. [11] design the probabilistic location-routing-inventory problem for perishable items with rescheduling and balking. Furthermore, Tirkolaee et al. [12] proposed a new two-tiered hierarchical structure optimization of allocation-routing for green energy-effective logistics systems. Then, they refined it to address the sustainable fuzzy multi-trip location-routing for healthcare waste management during the COVID-19 [13]. In addition, Torkayesh et al. [14] proposed a multi-objective optimization network concept for sustainable healthcare waste management. One crucial factor affecting facility location effectiveness is determining the distance between demands and the candidate facilities [15], [16]. The maximum set covering problem (MCLP) is a generic model used many times to optimize facilities’ coverage in terms of their services. This study has been reported to be successful in recommending new facility locations, such as selecting the area of public facilities [17], waste collection facilities [18], [19], military facilities [20], and medical test facilities [21]. The most
common approach to solving MCLP is the exact solution approach [22], [23]. Following the success of these studies, we are using the model to strategically determine the location of OPT plus in the region under the Iloilo City Health Office.

In this study, the MCLP is used to formulate the problem. Then, it is coded in A Mathematical Programming Language (AMPL) and solved the model by using CPLEX as an exact solver to optimize the community centre and playground location within the five districts based on the demand and distance per proposed location in every section.

The remainder of this paper's material is structured as follows: In Section 2, we discuss the mathematical formulation of the MCLP used to select the OPT plus facility. Section 3 discusses the outcome and analysis of the computational experiment. Section 4 presents the conclusion and recommendations for future research.

2. RESEARCH METHODS

The objective of MCLP is to locate several facilities on a network so as to maximize the required population or demand. If a facility serves a demand node, it is located closer to the demand node than the defined threshold. This predetermined threshold is commonly referred to as the coverage radius, which has a direct impact on the solution. It occurs when there are insufficient funds or resources to meet the demand of all nodes.

The description begins with some assumptions to initiate the model presentation of this article. When at least one facility is within a predetermined distance of a node, it is presumed that the node is covered. Additionally, each node could function as a host facility. In other words, the set of nodes is similar to the set of prospective facilities (Assumed that there are a set of demand nodes $I$ and a set of candidate sites $J$). In addition, it is expected that each node must satisfy a given level of demand. Additionally, proximity of the people to these facilities is desired.

The mathematical model is based on the MCLP of Church & Revelle [24]. In addition, a form of MCLP is taken into account. The MCLP mathematical program is shown as follows. First, we define problem input: $i$ and $I$ comprise the index & demand nodes. $j$ and $J$ are the index & set of qualified facility locations. $h_i$ indicates the population or demand at node $i$. $d_{ij}$ is the fastest route (or amount of time) between demand node $i$ and facility node $j$. $DC$ is the distance (or time) need for coverage. $P$ is the number of facilities to be established. $a_{ij}$ is a binary variable which equals if candidate site $j$ can cover ($d_{ij} < DC$) the demand nodes $i$ and zero otherwise.

![Fig. 1. Procedure and overall process of OPT plus](http://dx.doi.org/10.30656/jsmi.v6i2.4599)
Then, the decision variables are:

$X_j$ is The value of a binary variable is one when a facility is located at the $j^{th}$ node and zero otherwise.

$Z_i$ is a binary variable equal to one if node I is served by one or more facility within f and zero otherwise.

The objective function (1) maximizes the number of covered demands.

$$\text{maximize obj. } = \sum_{i \in I} h_i Z_i$$

Subject to:

$$Z_i \leq \sum_{j \in J} a_{ij} X_i \quad i \in I$$  \hspace{1cm} (2)

$$\sum_{j \in J} X_j \leq P$$  \hspace{1cm} (3)

Constraints (2) state the demand $i \in I$ unable to be covered until at least one facility that covered the demand node is chosen. Constraints (3) Limit the number of utilized facilities to no more than $P$.

There is an application of AMPL in this paper for the exact solution of MCLP. AMPL (A Mathematical Programming Language) is a known modelling language for large-scale problems [25].

3. RESULTS AND DISCUSSION

3.1. Case Problem and Description

Iloilo City Health Office is planning to establish a temporary community centre and playground as an annual program-related Nutrition that can ideally cater to the area’s districts. Specifically for OPT Plus, this program will provide supplementary and appropriate health and nutrition services for malnourished preschoolers. With the help of the MCLP model, establishing the community centre and playground will be optimally identified. A facility with 10 Km of vehicle transportation coverage is proposed for this project. The data gathered per barangay were arranged and classified per district concentrated as demand points for the problem. Fig. 2 shows the sections of Iloilo City with corresponding points.

Fig. 2. Seven districts points of Iloilo City

Fig. 3. UW/SUW per district of Iloilo City

Fig. 4. OW/Ob per district of Iloilo City

Fig. 5. Distances (Km) among district points in Iloilo City

From the 1st quarter survey of the Iloilo OPT Team in 2021, Fig. 3 shows the number of children evaluated with underweight/severely underweight (UW/SUW) conditions per district. While Fig. 4 shows the number of children assessed with overweight/obese (OW/Ob) conditions per district. This data is used as the demand values per district to optimize community centre and playground facility locations. Major daycare centres per district were identified for the facility location proposed by the city office. Distances from each point (in Km) of the daycare centre per district were determined through google maps, considering the use of road routes for vehicle transportation in Fig. 5 and Table 1.
Table 1. Day care centers and their locations

<table>
<thead>
<tr>
<th>Point</th>
<th>District</th>
<th>Name</th>
<th>Exact Location</th>
<th>Near Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Jaro</td>
<td>Jaro Day Care Center</td>
<td>Railroads line St., St. Brgy. Ma. christina Jaro, Iloilo City, 5000 Iloilo</td>
<td>B.C</td>
</tr>
<tr>
<td>B</td>
<td>Mandurriao</td>
<td>Mandurriao Day Care Center</td>
<td>Mandurriao, Iloilo City, 5000 Iloilo</td>
<td>A.C.E.F.G</td>
</tr>
<tr>
<td>C</td>
<td>Lapaz</td>
<td>Lapaz Day Care Center</td>
<td>Zone 3, Divinagracia, Lapaz, Iloilo City, 5000 Iloilo</td>
<td>A,B,E,D</td>
</tr>
<tr>
<td>D</td>
<td>Lapaz</td>
<td>Urban Poor Day Care Center</td>
<td>Block 5, Lapaz, Iloilo City, 5000 Iloilo</td>
<td>C.E</td>
</tr>
<tr>
<td>E</td>
<td>City proper</td>
<td>City Proper Multi-Purpose Day-care Center</td>
<td>Iloilo City Proper, Iloilo City, 5000 Iloilo</td>
<td>B.C.D.F</td>
</tr>
<tr>
<td>F</td>
<td>Molo</td>
<td>Molo Day Care Center</td>
<td>Bgy., Molo, Iloilo City, 5000 Iloilo</td>
<td>B.E.G</td>
</tr>
<tr>
<td>G</td>
<td>Arevalo</td>
<td>Arevalo Day Care Center</td>
<td>Osmeña St, Mohon, Arevalo, Iloilo City, 5000 Iloilo</td>
<td>B.F</td>
</tr>
</tbody>
</table>

Table 2. $a_{ij}$ for seven districts of Iloilo City

<table>
<thead>
<tr>
<th>Coverage</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
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<td>1</td>
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</tbody>
</table>

The mathematical programming language AMPL is used to code the mathematical formulation and solve by using CPLEX to determine the maximum covered demands and demands nodes and identify one facility for community centres and playgrounds. The AMPL utilises the concept of separation between model and data. A model file data was first established, and the parameters, decision variables, objective functions, and constraints were translated into AMPL. The first step is to solve the parameters defined in the mathematical formulation into the AMPL mathematical programming language. Next is to rewrite the data into AMPL based on UW/SUW and OW/Ob (varying demands but same demand and facility locations). Then, the mathematical optimization problem can be easily solved [26].

The result shows that Facility B is the optimal location for establishing the community centre and playground. All of the demands are covered for the chosen optimal facility B. For Underweight/Severely Underweight children, a maximum total of 646 are covered; for the Overweight/Obese, 1,041 are covered for the chosen facility. These are solved by one iteration only. All demand numbers are covered by Facility B with 10 Km coverage.

Further sensitivity analysis is conducted on different coverage radius and the number of facilities to the coverage percentage of the optimal results. Fig. 6 shows the sensitivity analysis on the effect of coverage radius on coverage percentages with P equals one. The result shows that the greater the coverage radius, the greater the coverage percentage can be obtained with the same number of facilities. Fig. 7 depicts sensitivity analysis on the effect of the number of facilities (P) to coverage percentages with a coverage radius of 2.5 Km. It is reported that with this setting, the minimum number of facilities needed equals 3. Using facilities more than that will result in the same demand coverage percentage.

http://dx.doi.org/10.30656/jsmi.v6i2.4599
Fig. 6. Sensitivity analysis on the effect of coverage radius on coverage percentages with \( P=1 \)

Fig. 7. Sensitivity analysis on the effect of the number of facilities (\( P \)) on coverage percentages with a coverage radius equal to 2.5 Km

The Iloilo City health officials can use this to locate their annual temporary community centre and playground in the district of Mandurriao, Brgy. Dungon-C Day Care Center. With this facility point, PUVs and private vehicles from other sections can easily access and offer common short routes in every other community.

3.3. Managerial and Theoretical Implications

Customers are often assigned to facilities based on their proximity to the facility. Much research has been done on models to help people decide where to put things like public facilities. This study enriches the knowledge pool by demonstrating the relevance of applying a mathematical optimization model, the Maximum Covering Location Problem (MCLP), to determine the optimal location that covers the area served by the community centre and playground facility.

In addition, this study allows practitioners to benefit from the theoretical and methodological knowledge of researchers, on the one hand, and it also helps researchers better understand the context, main concerns, difficulties, and limitations from a practical point of view, which is why it is important for this study. Another thing worth noting is that new models deal more closely with practical and important issues like where public facilities are.

4. CONCLUSION

In this paper, MCLP is coded in AMPL and solved using CPLEX. The approach to the problem is an exact solution using mathematical programming. There are further assumptions made, such as a node being covered if there is at least one facility within a predetermined distance. In addition, each node could serve as a facility host. In other words, the set of nodes and the set of potential facilities are identical (Assumed that there are a set of demand nodes \( I \) and a set of candidate sites \( J \)). In addition, it is assumed that each node has a certain amount of demand that must be satisfied. With them, an optimal solution for the location was determined.

The main limitation of our approach is that it cannot deal with a large-scale number of nodes due to the growing complexity of the problem. It is necessary to consider a more sophisticated approach, such as heuristics or metaheuristics algorithms \([27], [28]\). Furthermore, the demand of each node might be best characterized as an uncertainty parameter using stochastic or fuzzy approaches. Future research may explore using various heuristics/metaheuristics \([29], [30]\). The other has in-depth specific demand nodes and considers the program's cost, topography and studied coverage. Additional parameters consider validating the suitability of the solution further. Furthermore, to expand the problem not only limited to MCLP but also explore any models that can help further on the OPT Plus program limited to Iloilo City and their nationwide planning programs.

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