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A Mathematical Model for Optimal Allocation of Security Personnel on Campus Streets

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Abstract:
Positioning of securities guards on our campuses has been addressed in the literature, using experience-based judgment. In this paper, a mathematical approach is proposed using integer programming model, which addresses the optimal allocation of security guards on Campus Street. An integer programming model was developed. The study illustrates the model workability using federal polytechnic Ilaro campus with twenty-seven constraints and nineteen decision variables. The model was solved via Branch and Bound Technique. The solution indicates that the security guards should be placed on ten strategic junctions at a minimum cost against usual practice of sixteen locations. The model will act as a security support system for any tertiary institution or community that desires to minimize the cost of maintaining security guards.

Keywords: *Integer Linear programming (ILP), security guards, optimal solution, Decision variables, constraints*

1. Introduction

One of the most exciting moments of a school leaver is to leave his or her parents to live on campus. Nigeria recently is facing security challenges which has extended to many tertiary institutions. Many tertiary institutions have security guards to ensure the security of life and property on campus. It is imperative as well to develop a methodology in positioning the security guards at a strategic point in order to minimize cost and optimize sound and efficient security. A model is developed to facilitate the understanding of the security framework on our campuses. As such, the work concentrates on the best standing point of the security guards on our campuses using Federal Polytechnic Ilaro, Ogun State in Nigeria as an illustrative campus.

There have been different attacks on our campuses. Alemika, (2015) highlighted different recent attacks. See references therein for details.

The fact remains that security means far more than the absence of conflict. We know that lasting peace requires a broader attention to some areas such as education, health, democracy and human rights, unlawful weapons (kofi Anan, 1998). Therefore, occasional Kidnapping of lecturers and students calls for designing effective campus security system and this must be of National interest and concern, typically it is beyond the class room exercise.

Cult violence on our campuses cannot be over emphasized which began in early 1980s. Mediayanose, (2016) reported early cases of cult violence on our campuses. University of Nigeria 1985, University of Port Harcourt 1991, Obafemi Awolowo University 1999, Delta state University 2002. Findings of the studies conducted in (2008) reported that an average of 23,650 Nigerian undergraduate were indicted of cult-related offences between 2001 to 2008,(Amos and Oyewole, 2011).

Boko Haram, a deadly terrorist group which is campaigning against western education is determined on its threat to blow up our tertiary institution. There were many attempts by the national assembly to review the 33-years old law that forbids a police presence on campuses. But instead of returning police on our campuses, the security guards on our campuses can be placed at optimal location with modern securities communication gargets in terms of alertness. Below is a chronology of known attacks on our campuses in southern, western and Eastern part of the country.

Name of institution	Date	Notes
Auchi Polytechnic	10/10/19	A lecturer was kidnapped and eventually killed.
University of Ibadan	11/08/19	7 armed men attacked Abdulsalam Abubakar post graduate hall.
University of Ibadan	11/07/19	Armed men attacked Obafemi Awolowo female hall
Obafemi Awolowo university	01/06/19	Threatened attack
University of Port Harcourt	28/07/18	Gunmen attacked students lodge robbed with POS
University of Lagos	24/01/17	Attack on the vice-chancellor by the militant students
Federal university of Agriculture Abeokuta	26/08/16	The invisible gunmen attacked students' hostel
Federal university of Technology Owerri	31/05/13	Six gunmen attacked post graduate scholarship hostel

Table 1
Source: The Punch Newspapers

With these recent attacks, the government, school management and all stake holders at all levels should place high premium on lives and properties of human existence by positioning the security guards at the strategic location on our campuses. Therefore, this proposed model is intended to put smart to work in terms of campus security. Security does not need more guns and ammunition. It needs new rules, new techniques. Tackling new threats on our campuses with building extra artillery just adds complexity to the problem. This is the right time for us to rethink our approach to campus security. We hope that this proposed model is one of the approaches that will solve our campus security problems.

Vast literature on methods to strengthen security exists but there are little or no mathematical approach. Integer programming has been extensively used in different fields of life but its application to security is not really pronounced.

Ugur, (2016), his thesis focuses on prioritization of risks based on information security budget using linear programming. The model was applied to a case study, in which he tried to find the optimum risk response strategy in a hypothetical scenario with the rapid development of internet technology, rapid development of the campus security network must be embraced. Alimujiang and Ablimit, (2016) made an attempt to build an effective information security defense system that would provide effective protection of the xinjiang Uygur medical college.

Abdullah & Orukpe, (2016), proposed an integrated alerting system which uses both the internet protocol (IP) cameras and micro-switches for monitoring security situations, thereby providing an immediate alerting signal to the security personnel. The system has the input unit, processing unit, control unit and the power supply unit as its building blocks. The alert system developed by these authors was simulated with protens 8, and results show improvement in security monitoring.

Recognizing the significance of security as the pre-condition for the survival of the Nigeria people and nation, (Etannibi, 1967). He analyzed the constitution of the federal Republic of Nigeria provided in section 14 (1)(b) that the "security and welfare of the people shall be the primary purpose of government". The duty conferred on the government by this provision has not been discharged as the prevailing high level of human insecurity is on the increase (Etannibi, 1967). He just analyzed the state of insecurity in Nigeria without providing the solution.

In the search for solution, this paper utilizes the programming concept called integer programming to optimize the security architecture on our campuses.

2. Aim

This paper aims to mathematically develop campus security architecture model, by placing the security guards at appropriate locations at a minimum cost.

3. Objectives

- To identify campus major streets.
- To develop a realistic ILP security model.
- To allocate minimum number of security personnel to man the campus streets.

4. Methodology

ILP has been applied to large variety of real-life situations see Krasimira & Vassil, (2011) and Alenxandra & Martin, (2013). An integer programming is a linear programming technique with some or all the decision variables restricted to integer (or discrete) values. ILP deals with the problem of optimizing a linear function subject to a finite number of linear constraints.

$$Min/Max \sum_{j=1}^{n} c_j x_j$$

Subject to

$$\sum_{j=1}^{n} a_{ij} x_j \geq (\leq)(=) b_i$$

With $x_j \geq 0$ and are integers

for (i = 1,2 ...m) (j = 1,2...n)

Where x_j are the decision variables

c_j is the co-efficient of the objective function
a_{ij} is the co-efficient of the constraints.
bi is the boundary associated with the constraints.

5. Mathematical Formulation of the Model

5.1. Decision Variables

Let xj represent different junctions ranging from 1st junction to 19th junction
This implies ($x_1, x_2, \ldots x_{19}$.)

5.2. Objective Function

Minimize (Z)= $c_1x_1 + c_2x_2 \ldots c_{19}x_{19}$
Where $c_1, c_2, \ldots\ldots c_{19}$ are the cost attached to each security guard.

5.3. Constraints

The constraints for this work are basically the least number of security personnel per junction.

6. Model Assumptions

- Each of the campus main street is assumed to be served by at least one security guard.
- Logically assumption made is to place the security guards at street intersection such that each guard will serve at least two streets
- Cj in the objective function is assumed to be unity in location j except situation where wages of the security guard in j is different from others.
- Security guards are of the same cadre.

The general model governing the study is given below.

$$Min \sum_{j=1}^{19} c_j x_j$$

Subject to

$$\sum_{j=1}^{19} a_j x_j \geq b_i$$

With $x_j \in z^+$
Where $c_j = 1, a_j = 1 \; and \; b_i = 1$

$$x_j = 1,2 \ldots 19$$

$$x_j = 1, a\ guard\ is\ allocated\ to\ location\ j. x_j = 0, otherwise$$

7. Validation of the Model

The model is validated with federal polytechnic Ilaro major street layout of (see Figure 1). Fig 1.0 maps the major streets with 19 intersections. Therefore, the model is given below as a minimization model.

$$\min(z) = x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} + x_{11} + x_{12} + x_{13} + x_{14} + x_{15} + x_{16} + x_{17} + x_{18} + x_{19}$$

Subject to

$$x_1 + x_2 \geq 1 x_3 + x_4 \geq 1 x_6 + x_{11} \geq 1$$

$$x_1 + x_9 \geq 1 x_4 + x_5 \geq 1 x_6 + x_7 \geq 1$$

$$x_2 + x_3 \geq 1 x_5 + x_6 \geq 1 x_7 + x_8 \geq 1$$

$$x_2 + x_6 \geq 1 x_5 + x_{12} \geq 1 x_8 + x_9 \geq 1$$

$$x_8 + x_{10} \geq 1 x_{11} + x_{12} \geq 1 x_{17} + x_{16} \geq 1$$

$$x_9 + x_{14} \geq 1 x_{12} + x_{15} \geq 1 x_{17} + x_{18} \geq 1$$

$$x_9 + x_{10} \geq 1 x_{13} + x_{16} \geq 1 x_{16} + x_{19} \geq 1$$

$$x_{10} + x_{11} \geq 1 x_{13} + x_{14} \geq 1 x_{15} + x_{16} \geq 1$$

$$x_{10} + x_{13} \geq 1 x_{14} + x_{17} \geq 1 x_{19} + x_{18} \geq 1$$

With $x_1, x_2, x_3, \ldots x_{19} \geq 0 \; and \; are \; integers$

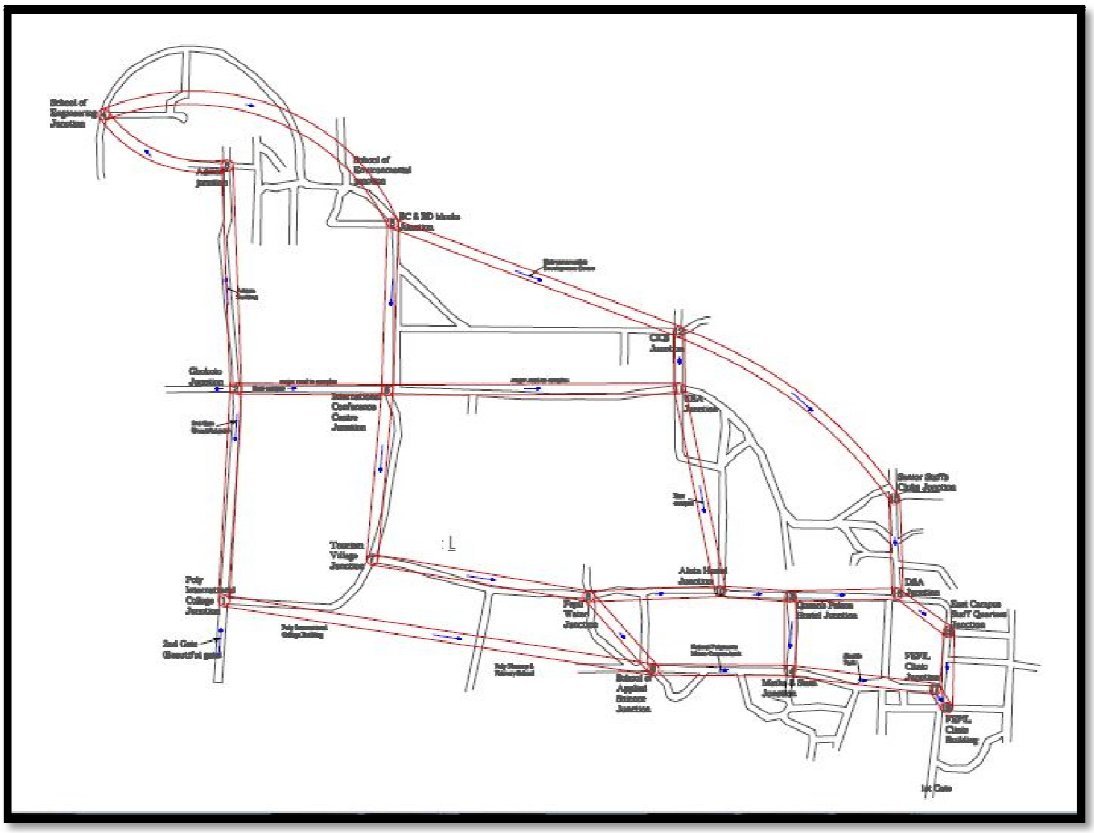

Figure 1: Major Campus Streets Federal Polytechnic, Ilaro

8. Data Analysis and Interpretation

The model engages Branch and Bound technique via TORA mathematical package.

Obj. Value	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}	x_{18}	x_{19}
10	0	1	0	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	0

Table 2: Summary of Results
Source: Extracted From TORA Package Output

The model output as presented in table (2) indicates optimum security guards allocated to strategic junction at a minimum cost. This study captures 19 major junctions on campus with considerable distance from one another. Security guards are optimally allocated to 10 junctions namely;

x_2 (2nd gate roundabout)
x_4 (School of engineering junction)
x_6 (International conference center junction)
x_7 (Tourism village junction)
x_9 (School of pure and Applied science junction)
x_{10} (JCI junction)
x_{12} (CICS junction)
x_{14} (Queens Hostel junction)
x_{16} (DSA junction)
x_{18} (Clinic Building junction)

The cost implication depends on how much the security guard in charge of the junction will take as wages. However, from the study we assumed that the security guards are of the same cadre. Therefore, 10 obtained as the objective value can be multiplied by the actual wages of the guards.

9. Conclusion

A large variety of different real-life problem in practice are formulated as integer optimization problem. To the best of the authors' knowledge non has laid emphasis on the positioning of guards on campus. The proposed model has successfully placed the security guards at the right position. This study suggests that for utmost security on Federal Polytechnic Ilaro campus, the security personnel should be placed at strategic junction on the campus streets. Based on the

output, just 10 security guards should be placed on 10 junctions out of 19 junctions. This will drastically minimize the security cost and maximize the security strength on the campus. This work remarks the application of ILP as a vibrant tool for accurately solving security challenges on our campuses.

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