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A MIP model for scheduling India's General Elections and police movement

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Abstract

Conducting the General Elections for the 543 members of the Parliament of India across the 833 thousand polling stations spread over the 35 States is a mammoth exercise. Deployment of the Central Police Forces is essential to complement the role of the State police during the elections. However paucity of Central Police Forces necessitates the conduct of elections over stages. This paper proposes and demonstrates a MIP model to (a) schedule the elections with a minimum number of stages (b) sourcing the appropriate number of security personnel from the most convenient Central Police Forces bases (c)scheduling movement of security personnel between stages with the objective of minimizing men-miles.

Keywords: OR in government; Scheduling; Logistics; MIP model;

1.Introduction

The Indian Republic comprises 28 States and 7 Union Territories. The Indian parliamentary form of government is federal in structure with legislative powers distributed between the Parliament of India and State Legislatures. The Parliament of India comprises two legislative bodies – the Upper House or the Rajya Sabha and the Lower House or the Lok Sabha. The members of the Rajya Sabha are indirectly elected by legislators of States and Union Territories comprising the Union of India. The 543 members of the Lok Sabha are directly elected by universal adult franchise by the electorate of all the 28 States and 7 Union Territories through the General Elections. The term of office of each Lok Sabha is five years from the date of its first meeting, unless dissolved earlier.

The total membership of the Lok Sabha is distributed amongst the 35 States and Union Territories (which will be referred to as States in the remainder of the paper) in such a manner that the ratio of the population to number of seats allotted to any State is nearly the same. The geographical area of the State is then demarcated into a number of territorial constituencies (with geographical boundaries), equal to the number of seats allotted, such that population of all constituencies in that State is nearly the same. Each constituency has a large number of polling stations distributed across the constituency such that voters can reach the polling stations to cast their vote with minimum travel.

The General Elections of India are the world's biggest election exercise. During the 2009 General Elections, a 717 million strong electorate exercised their franchise through 1.3 million Electronic Voting Machines deployed in 833 thousand polling stations spread across the length and breadth of India to elect 543 Members of the Lok Sabha from amongst 8 thousand candidates contesting the elections. The only other comparable elections are the

European Parliament elections with an electorate of 500 million and the US Congress elections with electorate of 312 million.

Elections in the past have been marked by instances of voter intimidation through violence or harassment in various forms, as well as clashes between political opponents(Scharff 2011). These incidences have been largely arrested through deployment of additional police forces during the polling process in order to bring peace, restore confidence in candidates and voters and thereby ensure fair and free elections.

The Constitution of India mandates that maintenance of law and order is the responsibility of the States. Thus while all States maintain police forces totaling about 1.5 million, the average police-population ratio for all the States is only 133 police per 100,000 (National Crime Records Bureau 2010) in comparison with average international ratio of 342(Stefan Harrendorf 2010). The Central Government therefore maintains Central Police Forces at various bases spread across the country, to complement the State police, whenever and wherever required.

Since the State police are the arm of the State governments, allegations of partisan conduct of police in enforcing law and order during the campaign closing stages and during the day of elections are likely. It has therefore become universal practice to deploy Central Police Forces, in addition to State police at all polling stations during the General Elections. However, the number of Central Police Forces that can be spared for deployment during the elections are not enough for manning all the polling stations of the 543 constituencies. Thus General Elections are spread over different days with each day covering a few states only, such that the required number of Central Police Forces can be deployed across all polling stations of all constituencies of those states. The days of elections are spread a few days apart to allow re-deployment of paramilitary personnel and allow them to be familiar with their constituencies. However, elections for all constituencies in a particular state are held on the same day. For example, the 2009 General Election was conducted in five stages on 16 April, 23 April, 30 April, 7 May and 13 May.

The movement of Central Police Forces from their bases to the polling stations in the different stages and their subsequent return to the bases is a gigantic exercise, requiring coordination between different agencies such as Central Police Forces' operations, Election Commission and State Chief Electoral Officers, District Election Officers, Railways, airlines and the Indian Air Force. In the 2009 General Election, 119 special trains, 65 sorties by Indian Air Force transport aircraft, 600 sorties by Indian Air Force helicopters and Air India chartered flights were used for the cross-country movement of Central Police Forces(Election Commission of India 2009).

The issue addressed in this paper is to devise a methodology to enable conduct of the General Elections for all the 543 parliamentary constituencies with (a) minimum number of stages, (b) with the available Central Police Forces and (c) with minimum police movement. Thus we wish to determine (i) the scheduling of elections for all 543 constituencies such that elections for all constituencies of a state are held together on the same day, and the elections are

completed within the minimum possible time (ii) scheduling movement of police from the bases to the polling stations and polling stations of a certain stage to polling stations in the next stage, such that the requirement of police personnel at the polling stations are met, appropriate number of police personnel from each base are deployed and the total number of men-miles traversed by the police personnel are minimized.

Scheduling and sequencing of activities or jobs on scarce resources such as machines has been an active area of research for more than half a century. Over the years, there have been various applications of the theory of scheduling to diverse areas such as assignment of planes to airport gates, scheduling tasks to a computer CPU (Pinedo 2008), aircraft routing and scheduling (Guy Desaulniers 1997), flight crew scheduling(Glenn W. Graves 1993), scheduling of classes in schools and universities (John J. Dinkel 1989), scheduling sport events (George L. Nemhauser 1998), scheduling surgeries (D. Sier 1997), work force scheduling (Vicente Valls 2009) and scheduling of maintenance activities(G. Budai 2006). The goals of scheduling are usually associated with improvement of turnaround, timeliness, throughput(Kenneth R. Baker 2009), maximizing profits, minimizing costs or satisfaction of certain constraints. However the author is not aware of any previous published work on the area of election scheduling and personnel movement.

This paper proposes and demonstrates a MIP model to (a) schedule the elections with a minimum number of stages (b) sourcing the appropriate number of security personnel from the most convenient Central Police Forces bases (c)scheduling movement of security personnel between stages with the objective of minimizing men-miles. The paper is organized as follows: the methodology is described in Section 2, followed by demonstration of methodology in Section 3 and discussions and conclusions in Section 4.

2. Methodology

2.1 The minimum number of stages over which the elections will be held throughout the country will be given by $\left\lceil \frac{\text{Total requirement of Central Police Forces at all polling stations of all 543 constituencies}}{\text{Total number of Central Police Forces available}} \right\rceil$.

2.2 The Central Police Forces personnel movement can be categorized in either of the following:

(a) movement from police bases to the constituencies before any particular stage of elections

(b) movement from constituencies to the police bases after any particular stage of elections

(c) movement from constituencies after any particular stage of elections to constituencies before subsequent stages of elections.

2.3 The following MIP model is proposed for scheduling the elections and police movement:

Indices used:

m: index used for election stages

r: index for states of India

j: index for constituencies of a state

b: index for police bases

Notation for data elements:
S_r: set of constituencies of State *r*
R: set of States of India
B: set of police bases
M:set of election stages
F: set of pairs of election stages, where each pair is a feasible 2-tuple of election stages between which police personnel movement is allowed; if the number of stages is 3, *F*={(1,2),(1,3),(2,3)} where the 2-tuple (1,2) indicates that movement of police personnel is allowed from stage 1 to stage 2.
c_{rj} : number of polling stations in constituency *j* of State *r*
p_{rj} : number of police personnel required for each polling station in constituency *j* of State *r*
c_b :number of police personnel available at base *b*
d_{bjr}:distance from base *b* to constituency *j* in State *r*
$d_{j_1r_1j_2r_2}$:distance from constituency j_1 in State r_1 to constituency j_2 in State r_2
L: very large number

Decision Variables:
x_{mrj}=1, if election for constituency *j* in State *r* is held in stage *m*
=0, if election for constituency *j* in State *r* is not held in stage *m*
x_{bjrm}:number of police moving from police base *b* to constituency *j* in State *r* for elections in stage *m*
x_{jrmb}:number of police moving from constituency *j* in State *r* after elections in stage *m* to police base *b*
$x_{j_1r_1m_1j_2r_2m_2b}$:number of base *b* police personnel moving from constituency j_1 in State r_1 after elections in stage m_1 , to constituency j_2 in State r_2 for elections in subsequent stage m_2; for example if m_1=1, m_2 could be 2 or 3 for a 3-staged election.

Thus the objective function is given by:
Minimize

$$\sum_{b\in B,m\in M,r\in R,j\in S_r}\left(\left(x_{bjrm}+x_{jrmb}\right)d_{bjr}\right)+\sum_{b\in B,(m_1,m_2)\in F,r_1,r_2\in R,j_1\in S_{r_1},j_2\in S_{r_2},r_1\neq r_2}\left(x_{j_1r_1m_1j_2r_2m_2b}d_{j_1r_1j_2r_2}\right)+\sum_{b\in B,(m_1,m_2)\in F,r_1,r_2\in R,j_1\in S_{r_1},j_2\in S_{r_2},r_1=r_2}\left(x_{j_1r_1m_1j_2r_2m_2b}\right)L$$

Subject to the constraints:

(1) $\sum_{m\in M} x_{mrj}=1,$ for all r∈R,j∈S_r

(2) $x_{mrj_1}=x_{mrj_2}$, for all m∈M,r∈R,$j_1,j_2\in S_r$

(3) $\sum_{b\in B} x_{bjrm}+$
$\sum_{b\in B,m_1\in M,(m_1,m)\in F,r_1\in R,j_1\in S_{r_1}} x_{j_1r_1m_1jrmb}\geq p_{rj}c_{rj}x_{mrj},$ for all m∈M,r∈R,j∈S_r

(4) $\sum_{m\in M,r\in R,j\in S_r} x_{bjrm}\leq c_b$,for all b∈B

(5) $x_{bjrm} +$

$\sum_{m_1 \in M,(m_1,m) \in F, r_1 \in R, j_1 \in S_{r_1}} x_{j_1 r_1 m_1 jrmb} =$

$x_{jrmb} + \sum_{m_1 \in M,(m,m_1) \in F, r_1 \in R, j_1 \in S_{r_1}} x_{jrmj_1 r_1 m_1 b}$,for all b∈B,m∈M,r∈R,j∈S_r

Explanation of the objective function: The first term of the objective function is the number of men-miles travelled by police personnel leaving the police bases before election stages and entering the police bases after completion of election stages. The second term is the men-miles travelled by police personnel travelling between constituencies after completion of an election stage and before commencement of subsequent election stage. The third term penalizes instances of police personnel staying back in a constituency after completion of the election stage.

Explanation of the constraints: Constraint (1) ensures that elections for any constituency in any State are held in a particular stage. Constraint (2) ensures that elections for all constituencies in any State are held in the same stage. Constraint (3) ensures that the required number of police personnel is available at all polling stations of all constituencies in the States where elections are being conducted for a particular stage. Constraint (4) ensures that the total number of police personnel travelling to constituencies is less than or equal to the available number of police personnel at that particular base. Constraint (5) ensures that the number of police personnel of a particular police base entering a particular constituency before a election stage equals the number leaving that constituency after the election stage.

3.Demonstration of methodology

3.1 The number of binary variables required for the MIP model proposed above is given by the product of the total number of constituencies (543) and total number of election stages. Thus if elections are held in 3 stages, the number of binary variables will be 1629.

The Central Police Forces personnel movement is generally by air, except the ‘last mile’ movement by road/rail to and from the constituencies. The average distance between constituencies, including air travel between nearest airports and ‘last mile’ road/rail movement, is 735 miles. The average ‘last mile’ distance of constituencies to the nearest airport is only 34 miles. Since the ‘last mile’ distance is quite small compared to the total inter-constituency distance, we can ignore the ‘last mile’ distance and reduce the problem to minimizing the men-miles travelled between airports only. The airport servicing the constituencies of a particular state can thus replace those constituencies; the airport will thus be servicing the total number of polling stations of those constituencies. For example, in Table 1 the Agra airport services 43 constituencies and the Gorakhpur airport services 37 constituencies of the state of Uttar Pradesh; thus Uttar Pradesh can be considered as having two ‘constituencies’ with the number of polling stations indicated in the table. Thus the number of binary variables reduces to 117 only, since the number of ‘constituencies’ have reduced from 543 to 39. This method of problem reduction has been used for demonstrating the methodology.

Sl.	**State-Serving Airport(s)**	**No of Members of the Lok Sabha**	**No of polling stations**	**Sl.**	**State-Serving Airport(s)**	**No of Members of the Lok Sabha**	**No of polling stations**
1	Andhra Pradesh-Hyderabad	22	35702	2	Arunachal Pradesh-Zero	2	2057

	Andhra Pradesh-Rajahmundry	20	31058				
3	Assam-Jorhat	14	18828	4	Bihar-Patna	40	57020
5	Goa-Dabolim Goa	2	1339	6	Gujarat-Rajkot	8	12912
					Gujarat-Vadodara	18	29656
7	Haryana-Hissar	10	12894	8	Himachal Pradesh-Kulu	4	7253
9	Jammu & Kashmir-Srinagar	6	9129	10	Karnataka-Hubli	28	46576
11	Kerala-Kozhikode	20	20510	12	Madhya Pradesh-Bhopal	29	47812
13	Maharashtra-Akola	14	25541	14	Manipur-Imphal	2	2193
	Maharashtra-Mumbai	34	57057				
15	Meghalaya-Shillong	2	2117	16	Mizoram-Aizawl	1	1028
17	Nagaland-Dimapur	1	1692	18	Orissa-Jeypore	21	31617
19	Punjab-Ludhiana	13	18846	20	Rajasthan-Jaipur	25	42699
21	Sikkim-Darjeeling	1	493	22	Tamil Nadu-Madurai	39	52158
23	Tripura-Agartala	2	3008	24	Uttar Pradesh-Agra	43	69654
					Uttar Pradesh-Gorakhpur	37	59792
25	West Bengal-Malda	42	66109	26	Chattisgarh-Raipur	11	20984
27	Jharkhand-Ranchi	14	23696	28	Uttarakhand-Dehradun	5	9003
29	Andaman & Nicobar Islands	1	347	30	Chandigarh- Chandigarh	1	422
31	Dadra & Nagar Haveli-Daman	1	161	32	Daman & Diu-Daman	1	94
33	NCT of Delhi-Delhi	7	11348	34	Lakshadweep-Agatti	1	40
35	Puducherry-Pondicherry	1	856				

Table 1: Number of constituencies and polling stations in each State

3.2 The following data is used for demonstration of the proposed method:

a. Number of police personnel to be assigned to each polling station has been assumed to be the same (4 numbers) for all polling stations.
b. Five Central Police Forces bases are assumed to be located next to nearest airports at Mumbai, Kolkata, Delhi, Shillong, and Hyderabad. Each base is assumed to have three hundred thousand policemen available for deployment.
c. Inter-airport distances

3.3 Since the (a) available Central Police Forces is 1.5 million, (b) the total number of polling stations is 833,701 and (c) 4 police personnel are assigned to a polling station, the minimum number of election stages is 3 as given in Section 2.1.

The MIP model described in 2.3 gives a solution of 1.005 billion men-miles. The model takes about 1.22 minutes for processing and solution using CPLEX 12.1.0 on a 1.3 GHz computer. The optimal schedule obtained is:the first stage elections are held in the 13 States (194 constituencies, 317,319 polling stations) of Chandigarh, Chattisgarh, Jharkhand, Karnataka, Lakshwadeep, Maharashtra, Meghalaya, Mizoram, NCT-Delhi, Puducherry, Punjab, Rajasthan, West Bengal; followed by second stage elections being held in the 15 States (162 constituencies, 230,670 polling stations) of Arunachal Pradesh, Bihar, Dadra & Nagar Haveli, Daman & Diu, Goa, Haryana, Jammu & Kashmir, Madhya Pradesh, Manipur, Nagaland, Orissa, Sikkim, Tamil Nadu, Tripura and Uttarakhand; followed by third stage elections being held in the 7 States (187 constituencies, 285,712 polling stations) of Andaman & Nicobar Islands, Andhra Pradesh, Assam, Gujarat, Himachal Pradesh, Kerala and Uttar Pradesh. The optimal movement of Shillong base Central Police Force personnel is given in Table 2 as an illustration. The optimal movement for all personnel, States and stages is given attached “Solution” file.

Movements	Airport (Number moved/ Total Number required)
Base to Stage 1 Meghalaya State	Shillong (11980/8468)
Base to Stage 1 Mizoram State	Aizawl(4112/4112)
Base to Stage 1 West Bengal State	Malda (59220/ 264436)
Stage 1 Meghalaya State to Stage 2 Nagaland State	Shillong to Dimapur(6768/6768)
Stage 1 Mizoram State to Stage 2 Manipur State	Aizawl to Imphal(4112/8772)
Stage 1 West Bengal State to Stage 2 Arunachal Pradesh State	Malda to Zero(8228/ 8228)
Stage 1 West Bengal State to Stage 2 Manipur State	Malda to Imphal(4660/8772)
Stage 1 West Bengal State to Stage 2 Sikkim State	Malda to Darjeeling(1972/1972)
Stage 1 West Bengal State to Stage 2 Tripura State	Malda to Agartala(12032/12032)
Stage 1 Meghalaya State to Stage 3 Assam State	Shillong to Jorhat (5212/75312)
Stage 1 West Bengal State to Stage 3 Assam State	Malda to Jorhat (32328/75312)
Stage 2 Arunachal Pradesh State to Stage 3 Assam State	Zero to Jorhat(8228/75312)
Stage 2 Manipur State to Stage 3 Assam State	Imphal to Jorhat(8772/75312)
Stage 2 Nagaland State to Stage 3 Assam State	Dimapur to Jorhat (6768/75312)
Stage 2 Sikkim State to Stage 3 Assam State	Darjeeling to Jorhat (1972/75312)
Stage 2 Tripura State to Stage 3 Assam State	Agartala to Jorhat (12032/75312)
Stage 3 Assam State to Base	Jorhat to Base(75312)

Table 2: Movement of Shillong based Central Police Force personnel

4. Discussion

The method demonstrated in Section 3, enables (a) scheduling of elections in all states within the minimum number of stages (b) sequencing the stages, such that the movement of Central Police Forces (measured in men-miles) is minimized and (c) sourcing the appropriate number personnel from the most convenient bases. This method can be utilized for scheduling and planning any nation-wide event requiring scarce resources.

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