Developing a Planning Model for Supplying First Aid Medicine after Cyclone in Southwest Coastal Areas of Bangladesh

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Abstract

In today's society that disasters seem to be striking all corners in Bangladesh and the globe, the importance of emergency management is undeniable. Much human loss and unnecessary destruction of infrastructure can be avoided with more foresight and specific planning. Most of the people die due to lack of medicines and proper treatment so it is necessary to supply first aid medicines right after any severe disaster. The goal of this paper is to develop a comprehensive model that involves transporting medicines from different supply sources to different distribution centers in response to Cyclones in the southwest coastal areas of Bangladesh to maximize the survival rate of the affected population, which is modeled using linear programming in order to find the optimal quantity of cartons containing medicines which will be supplied to affected people and also the optimal transportation cost and time. Excel Solver and simulation software Analytica® Optimizer has been used to model and solve this problem.

Keywords
Optimization, Linear Programming, Transportation Cost, Supply Chain.

1.0 Introduction

The immediate priority after a natural disaster is providing emergency first aid and medical services to injured persons. 'Disaster' is defined by The World Health Organization (WHO) as any occurrence that causes damage, destruction, ecological disruption, loss of human life, human suffering, deterioration of health and health services on a scale sufficient to warrant an extraordinary response from outside the affected community or area. The aspect of saving human lives, lies the field known as Disaster and Emergency Medicine which is the basis of dealing with these complex challenges.

Akkihal, A. R. (2006), considers a battery of mixed-integer linear programs for locating warehouses for non-consumable inventories required for the initial deployment of aid after a disaster occurrence. Nolz et al. (2010), provide a multi-criteria Meta heuristic based on evolutionary concepts for planning water distribution tours in disaster relief, determining the physical location of water tanks and selecting roads to be used for the transportation of drinking water.

Bangladesh is a country that has been intrinsically associated with natural disaster and vulnerability. The geographical vulnerability of our country lies in the fact that it is an exceedingly flat, low-lying, alluvial plain covered by over 230

rivers and rivulets with approximately 580 kilometers of exposed coastline along the Bay of Bengal (Rahman S.M. 2008). Bangladesh frequently suffers from devastating floods, cyclones and storm surges, tornadoes, riverbank erosion, and drought as well as constituting a very high-risk location for seismic activity because of its geography. Of the last 29 severe cyclones in Bangladesh that occurred in the period 1960-2012 (Doocy et al. 2013)

Time and cost is the main factors for supplying medicines after the occurrence of a cyclone which should be optimized correctly in advance. Linear programming method is used in this study to optimize time and cost in a proper way to supply an optimal quantity of cartons containing medicines. The purpose of this study is to supply first-aid medicine in an optimal quantity and to optimize the total transportation time and cost for supplying first-aid medicine according to their priority. This challenges require inter-disciplinary cooperation, building upon experience and a fundamental understanding of the unique characteristics of disasters as medical mass casualty events with long-term effects, both physical and mental.

2.0 Linear programming

To achieve the best outcome (such as maximum profit or lowest cost) in a mathematical model, linear programming (LP, also called linear optimization) method is used, whose requirements are represented by linear relationships. Linear programming is a special case of mathematical programming (mathematical optimization) (Bazaraa et al. 2011).

Linear programs are problems that can be expressed in canonical form as

Minimization $c^T x$

Subject to,

$Ax \leq b$ and $x \geq 0$

The expression to be maximized or Where x represents the vector of variables (to be determined), c and b are vectors of (known) coefficients, A is a (known) matrix of coefficients, and $(.)^T$ is the matrix transpose. The expression to be maximized or minimized is called the objective function ($c^T x$ in this case). The inequalities $Ax \leq b$ are the constraints which specify a convex polytope over which the objective function is to be optimized (Linear Programming, 2018). Standard form: Standard form is the usual and most intuitive form of describing a linear programming problem. It consists of the following three parts:

A linear function to be maximized (*Stack Exchange*)

e. g.

$f(x_1, x_2) = c_1 x_1 + c_2 x_2$

Problem constraints of the following form

e. g.

$a_{11} x_1 + a_{12} x_2 \leq b_1$

$a_{21} x_1 + a_{22} x_2 \leq b_2$

$a_{31} x_1 + a_{32} x_2 \leq b_3$
Non-negative variables

e. g.

$x_1 \geq 0$

$x_2 \geq 0$
The problem is usually expressed in matrix form and then becomes

$$\text{Max}\{c^T x \mid Ax \leq b \wedge x \geq 0\}$$

Other forms such as minimization problems, problems with constraints on alternative forms, as well as problems involving negative variables can always be rewritten into an equivalent problem in standard form.

3.0 Field survey

We selected Dacope Upazilla that is located in the North in Khulna district which is extremely disaster prone area (Setu et al. 2014). Three supply sources and five distribution centers were selected in this area. Figure 1. Illustrates the selected areas.
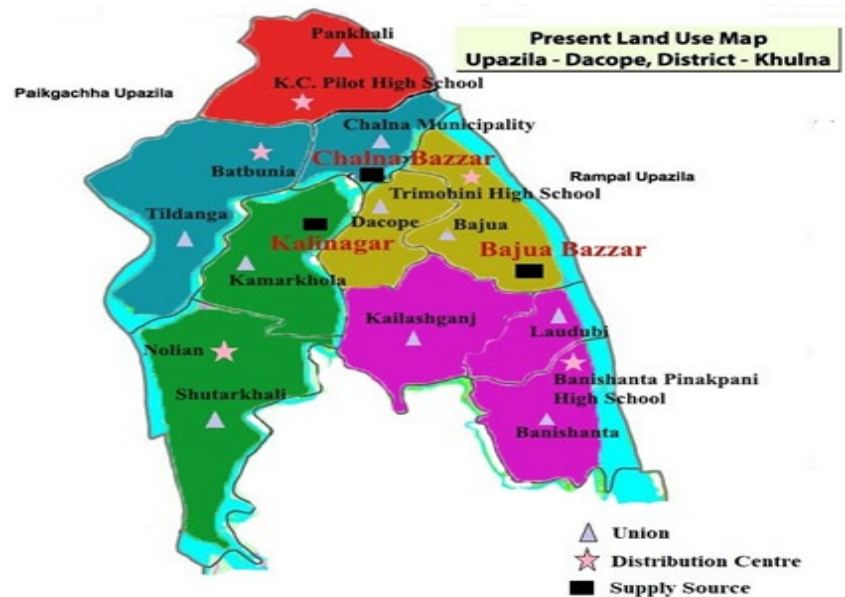
Figure 1. Map of Dacope Upazilla

4.0 Problem statement

Since the optimization model that will be developed is expected to be applicable to different phases of Cyclone, this section starts with depicting the scope of the problem which is followed by an extended description of the problem occurring after cyclone. The problem is to determine the optimal required number of medicine to supply after disaster from the supply source to the distribution center in order to obtain minimum transportation cost and time according the demand which depends on the severity of cyclone.

Number of families under each distribution center are, (Source: Local Union Parishad)

Batbunia-12756

Nalian-14362

K.C Pilot High School-10638

Trimohoni High School-13786

Banishanta Pinakpani High School-15326

Our emergency plan is basically for three days which starts from the day Cyclone strikes. Each carton will contain forty packets of medicines. A pickup truck will be used as the transportation medium and each pickup truck can contain around sixty cartons.

A single packet will contain following types of medicines:

Paracetamol (36 pc=4 person X 3 times in a day X 3 days)

Metronidasol (24 pc=4 person X 2 times in a day X 3 day)

Orsaline (12 pc=4 person X once in a day X 3 day)

Pain killer (24 pc=4 person X 2 times in a day X 3 day)

5.0 Mathematical Description

A mathematical description is formulated, called a mathematical model to represent the situation. The model consists of following components

The decision variables, objective function and constraints specific to the problem of this paper are given below:

Decision variables,

Three supply sources are symbolized as

$A_1 = Chalna\ bazar$
$A_2 = Bajua\ bazar$
$A_3 = Kalinagar$
Let the capacity of each supply point

$A_1 = 750$ Carton

$A_2 = 600$ Carton

$A_3 = 650$ Carton

Five distribution centers are symbolized as

$B_1 = Batbunia$
$B_2 = Nolian$
$B_3 = K.C\ Pilot\ High\ School$
$B_4 = Trimohoni\ High\ School$
$B_5 = Banishanta\ Pinakpani\ High\ school$
For Depression (wind speed up to 62 km/hr. (Cyclone, 2014)) the demand of each distribution center will zero as we are not supplying any medicine for that intensity.

For Cyclonic Storm (wind speed from 63 to 87 km/hr. (Cyclone, 2014)) we considering each packet of medicine will be distributed between two families. So, the demand in this level of cyclone is

$$= \frac{No.\ of\ family}{2\ X\ 40}$$

For Severe Cyclonic Storm (wind speed more than 87 km/hr. (Cyclone, 2014)) we considering each packet of medicine will be distributed for only one family. So the demand in this level of cyclone is

$$= \frac{No.\ of\ family}{40}$$

Table 1. Demand of each distribution center

Cyclonic Intensity	B1	B2	B3	B4	B5
Depression	0	0	0	0	0
Cyclonic Storm	160	180	133	173	192
Severe Cyclonic Storm	319	359	266	345	384

Table 2. Distance from supply source (SS) to distribution center (DC) (Unit km)

DC / SS	B1	B2	B3	B4	B5
A1	10	33	3	17	7
A2	25	22	27	5	7
A3	12	11	15	11	8

Table 3. Transportation time required for per shipment (unit min)

DC / SS	B1	B2	B3	B4	B5
A1	30	140	12	90	45
A2	120	45	35	15	25
A3	50	55	100	50	24

Table 4: transportation cost according to availability of road

		B1	B2	B3	B4	B5
A1	available	140	300	30	160	100
	Not available	180	340	60	190	130
A2	available	250	120	40	90	60
	Not available	270	150	75	125	115
A3	available	80	100	160	80	60
	Not available	105	130	180	115	95

Table 5: transportation time according to availability of road

		B1	B2	B3	B4	B5
A1	available	30	140	12	90	45
	Not available	45	155	80	210	145
A2	available	120	45	35	15	25
	Not available	285	175	95	145	135
A3	available	50	55	100	50	24
	Not available	120	150	205	135	115

6.0 Modeling the Problem using Excel Solver

The first step is to organize the spreadsheet to represent the model. After the implementation of the spreadsheet, next step is to use the Solver to find the solution. In the Solver, we need to identify the locations (cells) of objective function, decision variables, nature of the objective function (maximize/minimize) and constraints.

Step 1: A table in Excel for primary input was constructed first and figure 2 represents that table. The intensity of Cyclone, storage amount and priority was declared to the input. The priority was given as α, $1-\alpha$ where α represents priority of cost and $1-\alpha$ represents priority of time. The value of α must be in the range between 0 to 1.

Figure 2. Primary input

Step 2: Figure 3 containing demand and supply variables which vary with the cyclone intensity, here the supply is based on storage. Here, following formula was used to change the demand according the input

For distribution center B1,

Demand = VLOOKUP(Q24,P$17:U$20,2,FALSE)

Supply = IF(C$24>C$25,T24,ROUNDDOWN(T24*C$24/SUM(T$24:T$28),0))

Table 3. Demand Variations with Input			
Distribution Center	**Cyclone Intensity**	**Demand**	**Supply (Based on storage)**
B1	Severe Cyclonic storm	319	319
B2	Severe Cyclonic storm	359	359
B3	Severe Cyclonic storm	266	266
B4	Severe Cyclonic storm	345	345
B5	Severe Cyclonic storm	384	384
	Total	**1673**	**1673**

Figure 3. Demand variations with input

Step 3: At this step availability of roads from each supply source to each distribution center will be chosen from the list which is prepared by data validation.

Step 4: Costs for supplying per carton will be determined according to the availability of roads and the maximum cost among them will also be determined.

Step 5: Normalized cost per carton will be determined by dividing supplying costs for per carton by the maximum supplying cost.

Step 6: At the Next step time for transporting cartons of medicines for per truck from each supply sources to each distribution center sand the maximum time among them will be determined.

Step 7: Normalized time for per shipment will be determined by dividing supplying time for per carton by the maximum supplying time among them.

Step 8: Figure 4 represents another table that was constructed containing delivery, stock and requirements.

Here "Total In" is the quantity of cartons delivered to that particular distribution centers from supply sources.

i.e. For B1 it is "=SUM(R34:R36)"

And "Total Out" is the quantity of cartons delivered from that particular supply source to five distribution centers.

i.e. for A1 it is "=SUM(R34:V34)"

	Table 10. Decision Variables of Optimizing Time and Cost								
		Distribution Center							
		B1	**B2**	**B3**	**B4**	**B5**	**Total Out**		
Supply Source	A1						0	<=	750
	A2						0	<=	600
	A3						0	<=	650
	Total In	0	0	0	0	0	**0**		
		=	=	=	=	=			
		319	359	266	345	384			
	Total Normalized Value	0							

Figure 4. Decision variables of optimizing time & cost

Step 9: A cell was constructed that will calculate total normalized cost and it is showed in figure 5. To calculate total normalized cost, we need the function SUMPRODUCT. This function will automatically sum all the product of unit and cost per unit.i.e.

Total normalized cost =L5*SUMPRODUCT(AA13:AE15,R34:V36)+M5*SUMPRODUCT(AA20:AE22,R34:V36)

Figure 5. Total normalized value

Step 10: In this step Excel Solver was set up according to this problem. First Solver from Data tab was opened and located the Total Minimum Cost cell in to 'Set Objective' in solver (i.e. $T$40). As we wanted to minimize the function we will choose 'Min'. Figure 6 represents these steps.

Figure 6. Set objective at solver parameters

Step 11: In this step figure 7 shows, the changing variables (i.e. the optimal quantities) were located in to 'By Changing Variable Cells:' option of Solver.

Here changing cells will be ($R$34:$V$36)

Figure 7. Set changing variable cells at solver parameters

Step 12: Then constraints of this problem were added in Solver. There were three constraints

i.   Total Out is less than or equal to Stock.

    ii.   Total In is equal to demand.

    iii.   Delivery quantities are non-negative.

To add constrains we will click add button on Solver and locate each constrains.

i. Total Out is less than or equal to Stock which is showed in figure 8.

($W$34:$W$36 ≤ $Y$34:$Y$36)
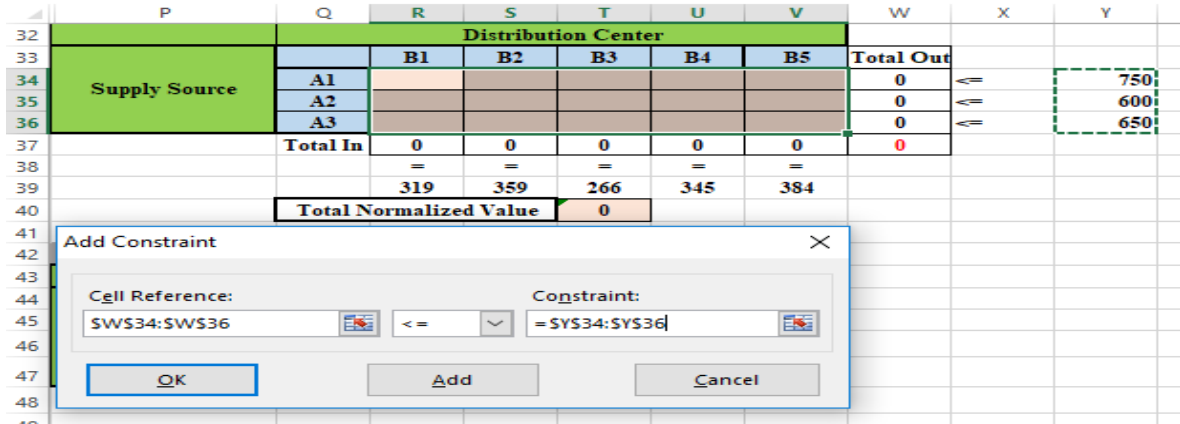
Figure 8. Set constraint for "Total Out" at solver parameters

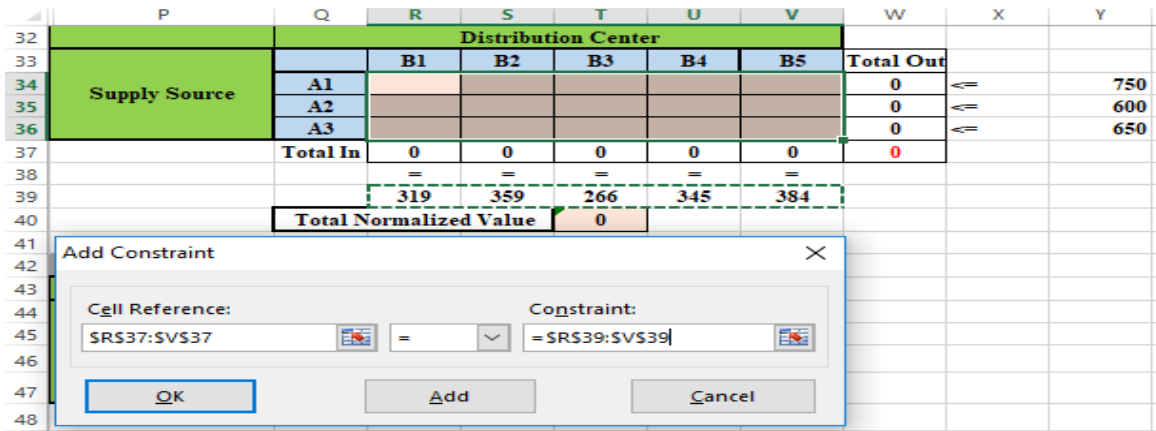ii. Total In is equal to demand that is showed in figure 9.

($R$37:$V$37 = $R$39:$V$39)

Figure 9. Set constraint for "Total In" at solver parameters

iii. Delivery quantities are non-negative (we will just select 'Make Unconstrained Variables Nonnegative') and solving method will be "Simplex LP" that is showed in figure 10.
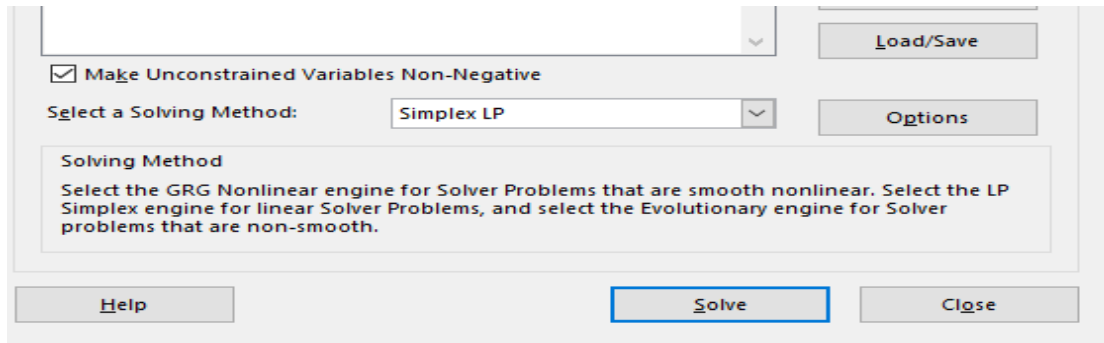
Figure 10. Mark Non-Negative & select Simplex LP at solver parameters

Step 13: when the setup was done, all that was left was to click on 'Solve' button. This way the following solution from Solver was found and it is showed in figure 11.

Figure 11. Optimized Solution after using Excel solver

Step 14: Now a table named summary was constructed to calculate total storage, demand. Supply, actual cost and actual time which is showed in figure 12. Here the following formulas were used

Total Storage, B24 =SUM(H5:H7)

Total Demand, B25=T29

Total Supply, B26=I20

Total Actual Cost, B27=SUMPRODUCT(Q5:U7,R45:V47)

Total Actual Time, B28=SUM(R53:V55)

Figure 12. Summary of the result

7.0 Simulation Analysis

After having the result by using Excel Solver, a simulation analysis will be performed to ensure whether the result is optimized or not.

The result found by using Analytica® Optimizer is shown both in graphical and numerical form. As we have three supply source, from Chalna bazar, we got the optimal solution that, the amount of carton should be supplied to Batbunia is157 carton and to K.C Pilot High School is 266 carton. No supply will be provided to other three distribution centers which is showed in figure 13.

Figure 13. Optimized output value from Chalna Bazar

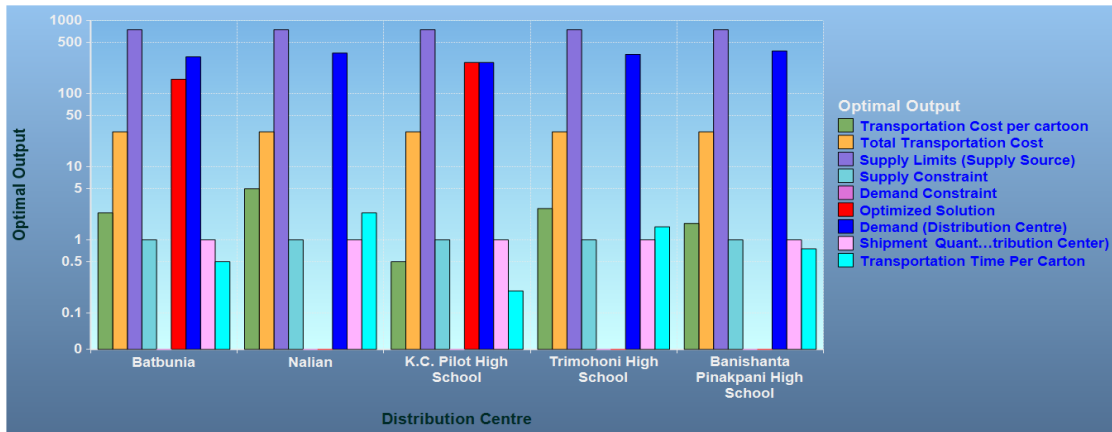The optimal value is displayed also in graph that is showed in figure 14.

Figure 14. Optimized output from Chalna Bazar (Graphical display)

Optimal quantities for other distribution centers will also be found by the similar way.

8.0 Results & Discussions

A table containing optimal solutions was found out for supplying medicines from different supply sources to different distribution centers after using excel solver. For instance, at severe cyclonic storm 157 is the optimal quantity of cartons containing medicines which will be supplied from supply source Chalna Bazar to Batbunia. To fulfill the

demand of this distribution center another supply source Kalinagar will supply 162 cartons which is also the optimal quantity. Total storage capacity was 2000 carton which will be supplied to fulfill the demand. Total demand is 1673 which was found out according to the cyclone intensity. After solving the model total supply will be equal to total demand which is also 1673. With the optimal solution, optimized transportation cost and time is also calculated which is 2570 TK. and 893 min respectively. For this same problem Analytica® optimizer simulation software was used to solve this. Result of the simulation software is a graphical display which presents similar optimal solution as excel solver. Since the output from both Excel Solver and simulation is same, the solution is considered optimal and effective to emergency response to Cyclone management.

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Biographies

Tamanna islam was born and raised in Dhaka, Bangladesh. She is a graduate and holds a Bachelor of Science degree in Industrial and Production Engineering from Khulna University of Engineering & Technology, Bangladesh. She has completed her internship at planning department in Novartis Bangladesh. She has done several projects related to her studies and mainly focused on supply chain management. She has conducted a great deal of fieldwork, conducting and supervising surveys, excavations, research programs, and lab work. Tamanna islam has completed research project with Md. Mahbubur Rahman, Lecturer of IEM Department, KUET. Her research interests include supply chain, optimization, simulation and linear programming.

Salim Hossain is the Executive Trainee of Fakir Apparels Ltd. He was born and brought up in Mymensingh, Bangladesh. He graduated in 2018 and earned B. S. in Industrial and Production Engineering from Khulna University of Engineering & Technology, Bangladesh. He successfully completed his project of making a water pump using waste materials. He has completed his one month internship at knit department in Interfab Shirt Manufacturing Ltd. He participated in several workshops and seminars and also a graduate from Bangladesh youth leadership center.