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OPTIMIZING THE ALLOCATION OF RESOURCES WITHIN THE CRITICAL MISSION TASKS OF MILITARY TRAINING USING THE TORA COMPUTER SOFTWARE: A CASE STUDY OF ARMY WING, NIGERIAN DEFENCE ACADEMY, KADUNA.

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ABSTRACT

In military training, resources have to be shared between concurrent training tasks. The methodology of the "Army training mix model" by KG Murty was applied to the Army wing of Nigerian Defence Academy pool of tasks for training cadets for effective making of officers. The optimal use of available resources to obtain training proficiency is needed. Observing the proficiency standard, the model determines the optimum distribution of resources among each task at a minimum cost. The model is a Mixed Integer Programming (MIP), which was implemented using Tora computer software.

Keywords: (optimization, allocation of resources, critical mission tasks, training proficiency, military training, tora computer software).

1.0 INTRODUCTION

Resource allocation is among the top challenges in military training, due to the complexity of military training project, scarcity of resources and the manual distribution method of resource allocation based on the distributor's scale of preference that cannot guarantee optimum and efficient solution to the distribution. This has been dealt with using this proposed model to aid the optimum distribution of resource allocation among the critical mission tasks.

In dealing with training resources, two main types of techniques have been used: resource allocation and resource leveling. Resource allocation (sometimes referred to as constrained-resource scheduling) attempts to reschedule the training tasks so that a limited number of resources can be efficiently utilized, while keeping the unavoidable extension of the training to a minimum. Resource leveling (often referred to as resource smoothing), on the other hand, attempts to reduce the sharp variations among the peaks and valleys in the resource demand of training tasks, while maintaining the original training duration. These techniques, as such, deal with two distinct sub problems that can only be applied to a project one after the other rather than simultaneously. Accordingly, they do not guarantee (either individually or combined) a project schedule that minimizes the overall project time or cost (Karshenas and Haber, 1990).

The model demonstrates how the Critical Mission Tasks (CMT) can be achieved at minimum cost; determine the allocation of cost for each company and how many times each of the CMTs should be repeated during the training cycle. The purpose of training is to attain proficiency on

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critical tasks, which can be defined as those activities that are essential to the successful training of the final year cadets and effective distribution of scarce resources.

The training cycle for cadets considered was a period of 12 months, which was the planning horizon for training decisions Army Cadets. The purpose of training is to attain proficiency on critical tasks, which can be defined as those activities that are essential to the successful performance of the cadets. Tasks are classified into various sections, depending on the maneuver during which training is obtained for them. The training tasks are classified into major and minor tasks. The major tasks are: military tactics, weapon training, map reading, signal communication, internal security, physical training, equitation and drill exercise. While the minor tasks are: current affairs, computer application, driving and maintenance, organization and administration, field engineering, military writing, man management, military law, French and first aid. The major tasks were considered in this study and are considered as critical mission tasks (CMTs). The CMTs are essential input and each CMT leads to a constraint in the model.

The question of challenging defence expenditure on arms and training is an idle exercise as there is no nation in the world today that does not spend heavily on defence and purchase of military equipment as a result of insecurity in every part of the world, yet most of these countries remain insecure, but the threat can be reduced by employing certain instruments to checkmate over-spending and wastage of human resources (Murty, 1994). Besides, the victory of soldiers and officers in battle depends on how well they are trained. Hence, there is the need to keep cadets trained in various techniques that will enhance their performance, since their training is based upon sophisticated ammunition and other logistics. Instructors need effective tools to assist them in combining existing, newly developed, and proposed training systems into less expensive strategies that can keep cadets trained at an acceptable level of skill with the limited resources available.

The first meaningful attempt to interoperate military models was the Simulator Networking (SIMNET) project initiated by the Defence Advanced Research Projects Agency (DARPA) in 1983 (Allusi 1991; Ground Schwab 1988). SIMNET was an effort to inter operate tank trainers to support unit (collective) training, and represented advances in a number of areas including, image generation technologies, low-cost simulator design, and networking technologies. This program resulted in the establishment of important principles for simulation interaction and the creation of a network messaging protocol to exchange essential data. SIMNET was the forerunner of the Distributed Interactive Simulation (DIS) protocols model. DIS attempted to generalize the SIMNET technology so that it could be applied to a wider variety of combat vehicle simulators such as trucks, helicopters, fighters, ships, and soldiers (Davis, 1995).

Analytical simulations are used to study problems like force composition, weapons effectiveness, and logistics issues. This community is strongly influenced by the science of operations research and may produce simulations very similar to those used for constructive level training. Analytical simulations usually differ in that they do not focus on interactive exchanges with people during a simulation run. This allows them to execute much faster or slower than real time without adversely impacting a human operator (Law 1991).

1.1 DATA COLLECTION AND ANALYSIS

A set of nine (8) Critical Mission Tasks (CMTs) at the final year level was selected. Using these CMTs and other input data, a mixed integer programming (MIP) problem of the model was formulated. The tasks are: military tactics, weapon training, map reading, signal communication, internal security, physical training, equitation and drill exercise, and are given code names as t1 to t8. The training modes are: Communication Exercise (Comm Ex), Advance & Quick Attack Technical Exercise Without Troops (A & Q ATTK TEWT), Sand Modeling Exercise (SM Ex), Harbour TEWT (Harb TEWT), Defence TEWT (DEF TEWT), Deliberate Attack (DEL ATTK), Withdrawal TEWT (WDR TEWT), Patrol & Ambush (PATR & AMB), Map Reading (MR), Slow & Quick Match (S&Q M), Skill at Arms & Bayonet fight (SAA BAF) and Obstacles Crossing (OBST CRS), and are given code names as m1 to m12.

The Army training mix model by KG Murty (1994) was applied for the minimization of the training cost. The model is:

Minimize total cost (Z) = $\sum_{\mathrm{m}=1}^{r}\left(\frac{\mathrm{n}}{\mathrm{p}}(C_m \mathrm{Y}_m)\right)$ ---------- (1)

Subject to:

$$\sum_{tm=1}^{r} a_{tm}x_{tm} \geq b_t \text{ ------------------------(2)}$$

and

$$0 \leq x_{tm} \leq U_{tm} \text{ --(3)}$$

Note that the equations (4) and (5) were used to calculate the parameters of b_t and a_{tm}:

b_t = standard level – ZPM for CMTs ------------------- (4)

$a_{tm} = (PR_{tm}(U_{tm}) - PR_{tm}(0)) / U_{tm}$ ------------------ (5)

The notations for all the data in the model above are:

Z = Total cost of training

n = Total number of cadets who need training.

p = number of persons who participate simultaneously in each session of the training.

C_m = Cost (sum of the operational costs) per session of training mode m.

Y_m = number of repetitions of mode m towards satisfying the proficiency constraint.

r = the number of times mode m is repeated during the cycle.

tm = task and mode (event and technique) of training of the tasks.

a_{tm} = average slope of the learning curve for the task-mode pair(t, m) in the range of interest $0 <= r <= U_{tm}$.

U_{tm} = upper bound on the number of repetitions of mode m that count towards satisfying the proficiency retention constraint corresponding to CMT t.

b_t = the minimal proficiency retention needed at the end of the training cycle in order to satisfy the proficiency constraint corresponding to t.

In the model problem in equation (1), n = 106 is the number of cadets in the final year Army class to be trained on each of the CMT and p = 36, 35 and 35 is the number of cadets in each company that was considered, all of which participate in every session of each mode. The cadets were divided into three companies; Alpha, Bravo and Charlie. The standard proficiency level for each CMT is given as 0.60 and $r \leq 10$. The Zero Practice Minimum (ZPM) and the upper bound on the number of repetitions of mode m that count towards satisfying the proficiency retention constraint corresponding to CMT t (U_{tm}) for all the companies is shown in the tables 1.0.

Table-1.0: Lists of tasks, training mode and their code names

List of Tasks	Code Name	Training Mode	Code Name	Task-mode (tm) for each task.
Military tactics	t_1	Comm Ex	m_1	t_1m_1, t_1m_2, t_1m_3, t_1m_4, t_1m_5, t_1m_6, t_1m_7, t_1m_8, t_1m_{12}
Weapon training	t_2	A & Q Attk	m_2	t_2m_1, t_2m_4, t_2m_{11}
Map reading	t_3	SM Ex	m_3	t_3m_1, t_3m_3, t_3m_9
Signal communication	t_4	Harb TEWT	m_4	t_4m_1, t_4m_2, t_4m_4, t_4m_8
Internal security	t_5	Def TEWT	m_5	t_5m_1, t_5m_5, t_5m_6, t_5m_7, t_5m_8
Physical training	t_6	Del Attk	m_6	t_6m_1, t_6m_{12}
Equitation	t_7	Wdr TEWT	m_7	t_7m_1, t_7m_{10}
Drill exercise	t_8	Patr & Amb	m_8	t_8m_1, t_8m_{10}
-	-	MR	m_9	-
-	-	S&Q M	m_{10}	-
-	-	SAA Baf	m_{11}	-
-	-	Obst Crs	m_{12}	-

TABLE-2.0: (Upper Bound of Repetition of Training Mode)

Task (t)	No of Mode Used (m)	No of Days	Platoon-1 (U_{tm})	Platoon-2 (U_{tm})	Platoon-3 (U_{tm})
t_1	9	3	09	09	07
t_2	3	2	06	05	04
t_3	3	2	06	05	05
t_4	4	4	08	10	08
t_5	5	2	10	07	06
t_6	2	2	04	06	05
t_7	2	2	04	06	05
t_8	2	3	06	06	06

The approximated (calculated) average slope of the learning curve (a_{tm}) using the formula in equation (5) for each platoon are given in the tables 3.0, 4.0 and 5.0.

TABLE-3.0:(Average Slope of Learning Curve of Platoon-1)

Task(t)	(U_{tm})	ZPM	$PR_{tm}(u_{tm})$	a_{tm}	b_t
t_1	09	0.54	0.95	0.05	0.06
t_2	06	0.36	0.80	0.07	0.24
t_3	06	0.50	0.80	0.05	0.10
t_4	08	0.50	0.90	0.05	0.10
t_5	10	0.13	1.00	0.09	0.47
t_6	04	0.24	0.70	0.12	0.36
t_7	04	0.19	0.70	0.13	0.41
t_8	06	0.28	0.80	0.09	0.32

TABLE-4.0:(Average Slope of Learning Curve of Platoon-2)

Task(t)	(U_{tm})	ZPM	$PR_{tm}(u_{tm})$	a_{tm}	b_t
t_1	09	0.54	0.95	0.05	0.06
t_2	05	0.36	0.75	0.08	0.24
t_3	05	0.50	0.75	0.05	0.10
t_4	10	0.50	1.00	0.05	0.10
t_5	07	0.13	0.85	0.10	0.47
t_6	06	0.24	0.80	0.09	0.36
t_7	06	0.19	0.80	0.10	0.41
t_8	06	0.28	0.80	0.09	0.32

TABLE-5.0:(Average Slope of Learning Curve of Platoon-3)

Task(t)	(U_{tm})	ZPM	$PR_{tm}(u_{tm})$	a_{tm}	b_t
t_1	07	0.54	0.85	0.04	0.06
t_2	04	0.36	0.70	0.09	0.24
t_3	05	0.50	0.75	0.05	0.10
t_4	08	0.50	0.90	0.05	0.10
t_5	06	0.13	0.80	0.11	0.47
t_6	05	0.24	0.75	0.10	0.36
t_7	05	0.19	0.75	0.11	0.41
t_8	06	0.28	0.80	0.09	0.32

The values of PR_{tm} (U_{tm}) above were derived from the learning curve graph of figure 1 above.

1.2 THE PROBLEM FORMULATION AND THE TRAINING MODEL SOLUTION

The values in tables (3.0, 4.0 & 5.0) and equations (1, 2, 3 & 4) were used to formulate the Integer Programming Problem as follows:

Let Z = Total cost, $x_1=t_1$, $x_2=t_2$, $x_3=t_3$, $x_4=t_4$, $x_5= t_5$, $x_6= t_6$, $x_7= t_7$, $x_8= t_8$.

$$\text{Min } Z = {}^{63}/_{21}(20x_1 + 21x_2 + 20x_3 + 14x_4 + 20x_5 + 18x_6 + 17x_7 + 10x_8)$$

$$\text{Min } Z = 60x_1 + 63x_2 + 60x_3 + 42x_4 + 60x_5 + 54x_6 + 51x_7 + 30x_8$$

subject to:

$$0.05x_1 + 0.07x_2 + 0.05x_3 + 0.05x_4 + 0.09x_5 + 0.12x_6 + 0.13x_7 + 0.09x_8 >= 0.06$$

$$0.05x_1 + 0.08x_2 + 0.05x_3 + 0.05x_4 + 0.10x_5 + 0.09x_6 + 0.10x_7 + 0.09x_8 >= 0.24$$

$$0.04x_1 + 0.09x_2 + 0.05x_3 + 0.05x_4 + 0.11x_5 + 0.10x_6 + 0.11x_7 + 0.09x_8 >= 0.10$$

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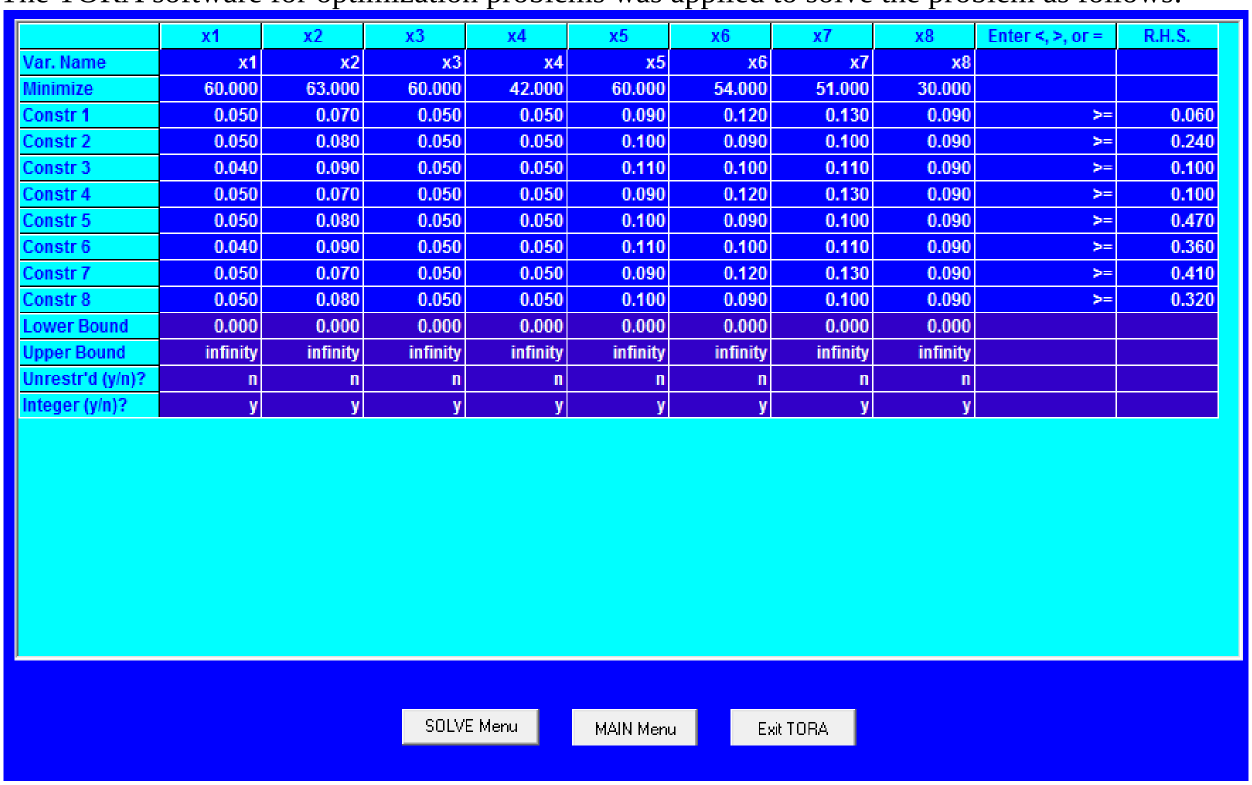
$$0.05x_1 + 0.07x_2 + 0.05x_3 + 0.05x_4 + 0.09x_5 + 0.12x_6 + 0.13x_7 + 0.09x_8 >= 0.10$$
$$0.05x_1 + 0.08x_2 + 0.05x_3 + 0.05x_4 + 0.10x_5 + 0.09x_6 + 0.10x_7 + 0.09x_8 >= 0.47$$
$$0.04x_1 + 0.09x_2 + 0.05x_3 + 0.05x_4 + 0.11x_5 + 0.10x_6 + 0.11x_7 + 0.09x_8 >= 0.36$$
$$0.05x_1 + 0.07x_2 + 0.05x_3 + 0.05x_4 + 0.09x_5 + 0.12x_6 + 0.13x_7 + 0.09x_8 >= 0.41$$
$$0.05x_1 + 0.08x_2 + 0.05x_3 + 0.05x_4 + 0.10x_5 + 0.09x_6 + 0.10x_7 + 0.09x_8 >= 0.32$$
$$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8 >= 0$$

The TORA software for optimization problems was applied to solve the problem as follows:



	x1	x2	x3	x4	x5	x6	x7	x8	Enter <, >, or =	R.H.S.
Var. Name	x1	x2	x3	x4	x5	x6	x7	x8		
Minimize	60.000	63.000	60.000	42.000	60.000	54.000	51.000	30.000		
Constr 1	0.050	0.070	0.050	0.050	0.090	0.120	0.130	0.090	>=	0.060
Constr 2	0.050	0.080	0.050	0.050	0.100	0.090	0.100	0.090	>=	0.240
Constr 3	0.040	0.090	0.050	0.050	0.110	0.100	0.110	0.090	>=	0.100
Constr 4	0.050	0.070	0.050	0.050	0.090	0.120	0.130	0.090	>=	0.100
Constr 5	0.050	0.080	0.050	0.050	0.100	0.090	0.100	0.090	>=	0.470
Constr 6	0.040	0.090	0.050	0.050	0.110	0.100	0.110	0.090	>=	0.360
Constr 7	0.050	0.070	0.050	0.050	0.090	0.120	0.130	0.090	>=	0.410
Constr 8	0.050	0.080	0.050	0.050	0.100	0.090	0.100	0.090	>=	0.320
Lower Bound	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
Upper Bound	infinity	infinity	infinity	infinity	infinity	infinity	infinity	infinity		
Unrestr'd (y/n)?	n	n	n	n	n	n	n	n		
Integer (y/n)?	y	y	y	y	y	y	y	y		

FEASIBLE SOLUTIONS (in improved order)

Subproblem	ObjVal, z	x1	x2	x3	x4	x5	x6	x7	x8
		x1	x2	x3	x4	x5	x6	x7	x8
14	330	0	0	4	0	0	0	0	3
15	300	0	0	3	0	0	0	0	4
16	210	0	0	1	0	0	0	0	5
22	192	0	0	0	1	0	0	0	5
61	180	0	0	0	0	0	0	0	6

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1.3 DISCUSSION OF RESULTS

The value of the objective function is 180. This indicates that the highest cost to be spent on training in a particular platoon on one specific task should not be more than 180 (as a unit in ₦1,000), if the proficiency retention cycle is strictly adhere to.

1.4 SUMMARY, CONCLUSION AND RECOMMENDATIONS

The main objective of this project is to minimize the cost of training cadets and still maintain their proficiency. It provides the NDA management with a sound scientific and a qualitative basis for optimal decision-making considering the sensitivity of defence in any nation.

Three main developments were made on this paper with respect to improving the resource management of training officer cadets:

(i) an effective improvement to resource allocation using optimization technique;

(ii) modeling the cost and tasks into integer programming problem;

(iii) optimum optimization of cost of training

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The optimization of military training is an important contribution that will significantly improves the allocation of resources in NDA Army wing to various training tasks.

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