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A Contextual Framework for the Quantified Strategy Model

1. THESIS RATIONALE

The aim of this thesis is to expound the findings of research conducted in order to develop a model or framework that allows for quantified facts to be considered in managing the *preparing for war* strategy benchmarked against the *war proper* or military strategy.

In order to focus the research that was undertaken, the following three research questions were formulated:

1. How can the extent of the many-to-many relationships that exist between a military strategy, its ends, ways and means be quantified?

2. If the relationships between a military strategy, its ends, ways and means, are quantified, and if the effectiveness of the force design elements is known, how shall that enable the quantification of the state's ability to execute its military strategy?

3. If the relationships between a military strategy, its ends, ways and means are quantified and if the effectiveness of the force design elements is known, how will it aid decision-making about the acquisition of the future force design?

1.1. DEFINITION OF MILITARY STRATEGY

In order to build a quantifiable model of a military strategy, we have amended Lykke's[1] definition of military strategy to read as follows:

[1] Lykke, A.F. Jnr., Defining Military Strategy, *Military Review*, January – February 1997, p. 183 – 186.

> *Military Strategy* is a plan at the military strategic level of war that consists of a set of military strategic ends, ways and means and the relationships between them.

By providing in the definition for the relationships between a military strategy's ends, ways and means, we were able to formulate a ranked tree, M, that we could populate with information about the relationships within a military strategy.

1.2. RANKED TREE

The ranked tree represented a military strategy's ends, ways and means by vertices at six defined levels of abstraction. The root of the tree represents the highest level of abstraction whilst terminal vertices represents the lowest level of abstraction. The six levels are as follows:

- Level 0: The root of the tree representing the military strategy.
- Level 1: The military strategy's ends.
- Level 2: Military Missions. The higher order military strategic ways.
- Level 3: Military Tasks. The lower order military strategic ways.
- Level 4: Operating Systems. The higher order military strategic means.
- Level 5: Force Design Elements: The lower order military strategic means.

The ranked tree, M, allowed for the quantification of the degree to which entities represented by the vertices in the tree enabled entities represented at their predecessor vertices. We have shown that it is possible to quantify these relationships by the use of analytical models, heuristics and the utilisation of military judgement.

Research has led to the formulation of quantified measures for

- the degree to which entities represented by the vertices in the tree enabled entities represented at their predecessor vertices, $\upsilon_{\langle\varphi\rangle}$ and $\rho_{\langle ijklm\rangle}$;
- the degree to which entities represented by the vertices in the tree enabled the entities represented at the root or military strategy, $\tilde{\upsilon}_{\langle\varphi\rangle}$; and

- the degree to which a set of vertices at a particular level of abstraction enabled the entities represented at the root or military strategy, w_f, w_s, w_t, w_m and w_e.

In order to show how a ranked tree, M, may represent a military strategy, a military strategy for South Africa was derived from the South African Department of Defence's Strategic Plan and cast into such a tree structure. The following numbers of vertices in the tree were defined:

- 1 root vertex to represent the military strategy.
- 3 vertices to represent the military strategy's ends.
- 9 vertices to represent the military missions.
- 34 vertices to represent the military tasks.
- 108 vertices to represent the 13 operating systems.
- 505 terminal vertices to represent the 84 force design elements.

The degree to which entities represented by the vertices in the tree enabled entities represented at their predecessor vertices, $v_{\langle\varphi\rangle}$, was quantified by the utilisation of the military judgement of a panel comprising of general and senior officers. This information was used to demonstrate how this model or framework could be used to augment decision-making by supplying quantified measures.

1.3. WEAPON SYSTEM EFFECTIVENESS

Subsequently we have investigated the notion of weapon system effectiveness. We have concluded that although the WSEIAC state space definition of systems effectiveness is very elegant, it is not suitable for general use as its computational size is exponential to the number of sub-systems that need to be explored. We have then adopted a systems space definition of weapon system effectiveness,

$$P(E) = P(A_O)P(D|A_O)P(C|A_O \cap D)$$

where A_O is the system's availability, D is the system's dependability and C is the system's capability. The short hand notation being:

$$E = A_O DC .$$

We then developed measures of effectiveness at all six of the levels of abstraction within M. Thus we now have measures of effectiveness for the force design in terms of

- force design elements, E^{US};
- operating systems, E^{OS};
- task forces, E^{TF};
- military missions, E^{M};
- strategic ends, E^{E}; and the
- military strategy, E^{R}, itself.

Thereafter we have sequentially researched the concepts of availability, dependability and capability.

From the study of availability we have developed measures for a wide array of quality indicators where these indicators are based on the cost of the product or service to the military. Thus, we have expressed these quality measures in terms of the potential loss of availability to the military. In order to achieve this we had to assume that the activities such as corrective and preventative maintenance are not mutually exclusive. This assumption has aided in formulating more accurate measures that will allow for the corporate and unit management of the following factors by the setting of goals and objective in terms of these measures:

- Quality of the logistic support system to support the force preparation and force employment activities.
- Quality of the human resource support system to support the force preparation and force employment activities.
- Quality of the design and production of main equipment.
- Quality of the maintenance philosophy.
- Quality of the logistic supply process.
- Quality of the health of individuals within the organisation.
- Quality of integration training at force design element level.

- Quality of the leave policy and the management thereof.
- Quality of discipline within the organisation.
- Quality of the human resource supply chain inclusive of recruiting, training and timely appointment.

We have defined two methods for establishing dependability for a force design element. Firstly, Blanchard and Fabrycky[2] suggests that, for force design elements that do not have organic support, dependability

$$D = f\left(R_1, \ldots, R_n\right)$$

where R_i is the reliability of the ith sub-system. Where we have force design elements that have organic support systems, we have defined dependability as a function of mission up time over the total mission time.

We have noted that finding measures for force design element's capability could prove to be complex. The complexity of finding measures for capability is directly attributable to the complexity of the force design element under consideration. We have shown that although these complex measures are not always directly identifiable as probability functions, they are monotone non-decreasing functions in the interval [0,1] and they relate indirectly to the probability of being capable to execute the force design element's designed for function. Thus, we propose that they are of sufficient quality to be utilised as measures of capability.

We have concluded the report on the research as it relates to weapon system effectiveness by

- developing a set of combat readiness criteria based on weapon system effectiveness;
- quantifying the probability and impact of risks as they pertain to the military's force preparation and force employment systems; and
- developing guidelines for the utilisation of the measures of quality that we have developed.

[2] Blanchard, B.S. and Fabrycky, W.J., *Systems Engineering and Analysis*. 2 ed., New Jersey: Prentice Hall, 1990, pp. 355–358.

1.4. ACQUISITION OF MAIN EQUIPMENT

The research to explore how the preceding model could be utilised in decision-making as it relates to the acquisition of main equipment has led to the following developments:

- Early warning of the fact that force design elements or their sub-systems should be renewed is given by monitoring measures for inherent availability or force design element effectiveness. The ageing of main equipment will become apparent in both these measures.
- The decisions about which systems to acquire could be supported by the quantified measures for effectiveness as guaranteed by the supplier and the predicted life-cycle cost of the equipment.
- The decisions about which projects to execute in order to fit into the budget and, at the same time, optimise the effectiveness of the force design to support a military strategy may be achieved by taking the projected difference in effectiveness and projected difference in life-cycle cost into account.

2. MANAGEMENT LEVELS IN THE MILITARY

In this chapter, we shall consider a medium to small sized military such as the South African National Defence Force only. The implications for larger military establishments may be deduced from this, but it would require some additional research. Medium to small sized military establishments are normally structured to allow for at least four levels of management, *viz.*,

- unit level,
- formation level,
- service and division level, as well as the
- high command or corporate level.

The military, complete with its establishment table is termed the *force structure*. The force structure comprises of the force design, command and management structure and the support structure. The *force design* is the fighting instrument of the military. The *command and management structure* comprises the leadership elements of the force structure. The *support structure* acts in support of the force design and contains logistic and human resources support elements.

Whereas the force design and the support structure are mainly found at unit level, the command and management structure is normally embodied at the corporate, service and divisional as well as the formation levels.

The purpose of the high command is to set objectives at the military strategic level. This would include a preparing for war strategy and a military strategy.

The services and divisions operate at the operational level. The services prepare forces to enable the military strategy. The support division supports both the preparing for war and the waging of war. The operations division wages war. The services and the support division are normally organised in type formations whereas the operations division is organised in task organisations.

Formations manages the attainment of the support, force preparation and operations objectives. Units execute the necessary tasks in order to attain the support, force preparation and operations objectives.

Whereas the distinction between the support structure and the force design is relatively clear at the service and division as well as at the formation level, the support structure and force design is often integrated at unit level. For example, an infantry battalion comprises certain logistic, training and other human resources elements as well as the battalion to be deployed as part of the force design.

Moreover, a particular force design might be contained in more than one unit. For example, the motorised infantry may consist of several battalions, an air force base might contain several aircraft squadrons and a flotilla might contain several ships.

3. A SYSTEMS APPROACH TO MANAGEMENT

Modern management practice prescribes a systems approach to an entity's business. Jablonski[3] states that the manager must focus on the process as well as on the results. A process may be viewed as the transfer function of a system[4]. Thus, the system houses the process to be managed.

A broad systems management concept is delineated in Figure 6.1. The force preparation process is central to the concept. The integration of force design elements happens in this process. The acquisition community provides main equipment whereas the force support process provides logistic and human resources support to the force

[3] Jablonski, J.R., *Implementing TQM - Competing in the Nineties through Total Quality Management.* 2 ed., Technical Management Consortium, Albuquerque, 1992, p.46.
[4] Engelbrecht, G.N., *Simulation: study guide 1 for OPS303-Q.* Revised edition, Pretoria: University of South Africa, 2001, pp. 10.

preparation process. The force preparation process provides combat ready force design elements or sub-sets thereof to the force employment process. The acquisition community and the force support process may be considered to be force support structure whilst the force preparation process is a mixture of the force support structure and the force design. The force deployment process is purely in the ambit of the force design.

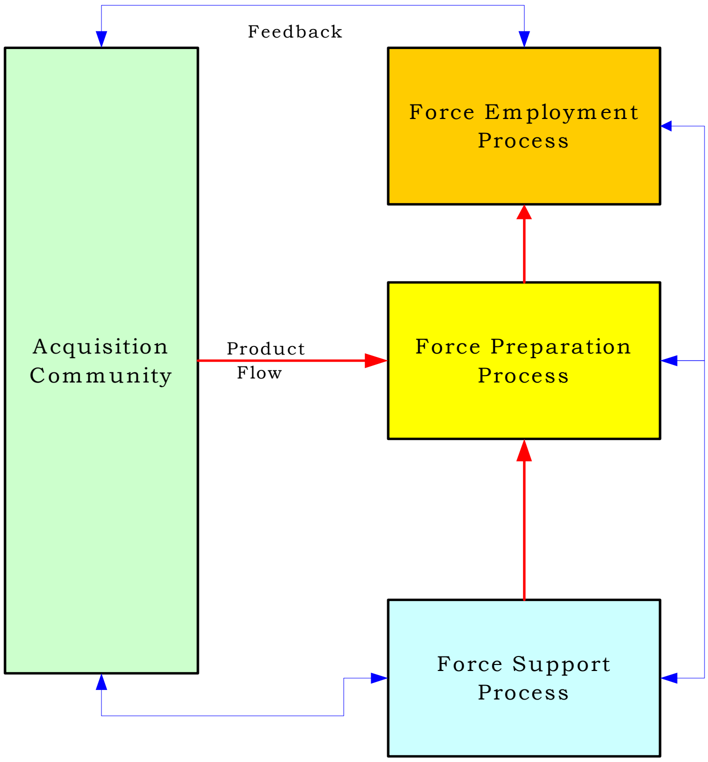

Figure 6.1: A Systems Management Concept for the Military

Feedback mechanisms exist between the four entities in the systems management concept. The Quantified Strategy Model provides for quantified feedback to regulate the flow of the various process outputs.

4. UNITS

In order to assess the effect of the Quantified Strategy Model at unit level, we shall discuss the effectiveness measurement of force design element within unit lines and the use of the information so obtained to the manage the unit.

4.1. FORCE DESIGN ELEMENT EFFECTIVENESS

Suppose a force design element such as the special infantry comprises of one unit only, then its effectiveness is given by $E = A_O DC$. When a force design element spans n units, then its effectiveness is given by

$$E^{US} = \frac{1}{n}\sum_{i=1}^{n} E_i^U \qquad (6.1)$$

where E_i^U is the effectiveness of the *i*th force design element component of the unit. Note that we assume that all units that comprise a force design element make an equal contribution to the force design element. Suppose we have a force design element that is made up of sub-elements in units of unequal value, then the effectiveness of the force design element would be

$$E^{US} = \sum \omega_i E_i^U \qquad (6.2)$$

where ω_i is the weight of the *i*th unit. Note that (6.2) would be used where, for example, some units are considered to be battalions and other unit considered to be companies.

The entry point into the Quantified Strategy Model is considered to be a force design element whereas the input information regarding effectiveness is obtained at unit level.

4.2. UNIT MANAGEMENT

Fact-based decision making is a cornerstone of modern management practice[5]. As the factors influencing effectiveness may be most effectively analysed by using quantitative data, the measurement of effectiveness at unit level enhances fact based decision-making. The use of quantitative data for analysis will be discussed as they appertain to the concepts of availability, dependability and capability.

4.2.1. Availability

As we have seen, a measure of availability provides us with a number of quality measures. These measures may be grouped in two categories, which relate to logistics and human resources respectively.

4.2.1.1. *Logistics*

We have defined quality measures for the

- design and production of main equipment;
- maintenance philosophy; and the
- logistic supply process.

[5] Jablonski, J.R., *op.cit.*, p. 48.

The quality measure for design and production of main equipment is based on corrective maintenance time. Information gained from the model will impact on unit policies regarding the inventory for spare parts and workshop capacity.

The quality measure regarding the maintenance philosophy is based on preventive maintenance time. The aptness of the maintenance philosophy may be scrutinised in conjunction with corrective maintenance requirements. With the aid of the information available from the model, the balance between foreseen corrective maintenance activities and planned for preventive maintenance activities may be managed effectively.

The quality measure regarding the logistic supply process would impact on the inventory and will also serve as an indicator of the negative effect to the unit that may be ascribed to a lack of quality in the logistic supply process.

4.2.1.2. *Human Resources*

We have defined quality measures for the

- health of personnel in the organisation;
- integration training;
- management of the leave policy;
- discipline within the unit; and the
- human resource supply chain inclusive of recruiting, training and timely appointment.

The quality measure regarding the health of individuals in the unit will impact on the planning regarding staffing and required health facilities and the quality measure regarding integration training will influence entry requirements for new members into the force design element of the unit.

The quality measure regarding the management of the leave policy will allow for a more novel approach to the scheduling of leave. For example, in the US Navy, nuclear submarines have two complete crews. Whilst the one crew is at sea, the other crew is being maintained by means of continuation training and leave. Also, the ashore crew is used in the base support structure. This allows for a support team with intimate knowledge of their client's business.

The quality measure regarding the discipline within the unit points to the effectiveness of the unit leadership. Problem areas may be identified and rectified before disciplinary problems become unmanageable.

The quality measure regarding the human resource supply chain inclusive of recruiting, training and timely appointment will aid in deliberate planning to minimise the effects of poor quality in the human resource supply chain by stating requirement early enough to be satisfied timely and by ensuring proper specification of entry requirements.

4.2.2. Dependability

The measurement of dependability will impact directly on the preventative maintenance policy and the specification of the organic support capabilities within the force design component of the unit. Improvement of the preventive maintenance policy will lead to an improvement in dependability. Likewise, mission down time may be reduced if the necessary organic support is deployed with the force design component of the unit.

4.2.3. Capability

The measurement of capability allows for an objective review of the success of the force preparation process within the unit. Man and machine are integrated by means of doctrine and the capability measure reflects that integration. It encompasses the combat skills required by the operators and their expertise in operating the equipment. Furthermore, it reflects the total capability to be used under battle conditions.

The capturing of data regarding capability allows for the identification and rectification of procedures and drills that are sub-standard. Not only will it point to deficiencies in training, but also to sub-standard drills and procedures. Thus, this measure may also be used to improve the quality of doctrine.

5. FORMATIONS

Formations are normally charged with the responsibility to manage one or more force design element. The Quantified Strategy Model aids the command and management structure at the formation level in the preparation of forces for deployment. Suppose we have a requirement for three combat ready (CR1) units to allow for a particular force design element to be effective. From Figure 6.2, we see that, given there are seven such units and that $E^{US} = 0.5$, the probability is 90% that we shall have at least three combat units ready for deployment at any given time.

Likewise, if under the same circumstances, we only have four such units, then we may say that we shall, with a likelihood of about 47%, have at least three units combat ready at any given time. Thus, our measurement of effectiveness provides us with quantified facts regarding force preparation at the formation level.

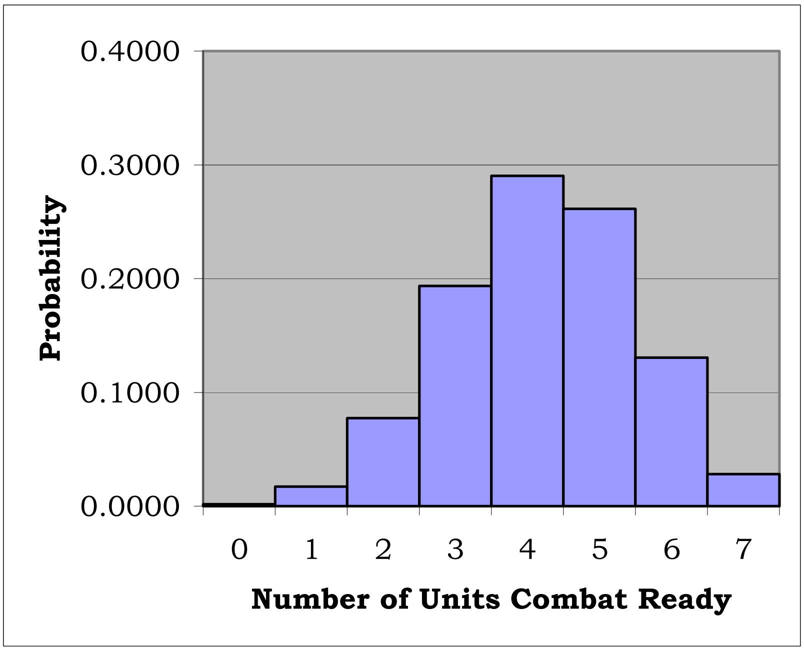

Figure 6.2: Binomial Distribution of Units being Combat Ready

Furthermore, the analysis of the quality measures described previously may lead to the adjustment of service levels between the units belonging fully to the support structure and the units charged with force preparation. For example, if long logistic delay times are experienced, the policy regarding inventory in the support structure may have to be adjusted or the procurement procedures and contracts with suppliers will have to be improved.

The model will further aid the formation commander in the setting of minimum effectiveness standards to be achieved by units. For example, for a given likelihood of achieving three combat ready units, he could calculate the effectiveness required of the force design components of his units to have three ready.

An analysis of the capability data would reveal general weaknesses and strengths in the force design elements. For example, if a question on voice procedure is present in all mark sheets, then the general state of voice procedure may be ascertained.

Thus, the Quantified Strategy Model will aid in fact-based decision making in formations.

6. SERVICES

The Services are, *inter alia*, responsible to ensure that combat ready forces will be available in the long term. To this end they must evaluate the requirement for reserves and the maintenance of the effectiveness of the force design.

Suppose it is possible to achieve $E^{US} = 0.5$ for the various units' contribution to a specific force design element, then the size of the reserve may be calculated by standard statistical methods. For example, the probabilities that a certain number of units will be combat ready given a reserve of 7, 6, …, 3 respectively is given in Table 6.1.

		Total Number in Inventory				
		7	6	5	4	3
Number of Units Combat Ready	0	0.0016	0.0041	0.0102	0.0256	0.0640
	1	0.0172	0.0369	0.0768	0.1536	0.2880
	2	0.0774	0.1382	0.2304	0.3456	0.4320
	3	0.1935	0.2765	0.3456	0.3456	0.2160
	4	0.2903	0.3110	0.2592	0.1296	Nil
	5	0.2613	0.1866	0.0778	Nil	Nil
	6	0.1306	0.0467	Nil	Nil	Nil
	7	0.0280	Nil	Nil	Nil	Nil

Table 6.1: Binomial Distribution of Units being Combat Ready given various Reserve Levels

By this method, quantifiable management information is available to the decision-makers regarding the impact of reserves on combat readiness.

In order to maintain the effectiveness of the force design, Services are required to evaluate the present effectiveness of the force design and the observed trends in the effectiveness of the force design so as to estimate when it will fall below acceptable levels. The Quantified Strategy Model is static in nature. Thus, it gives a snapshot of the effectiveness of the force design at a given time. However, by storing the information, time series data may be obtained to forecast trends in effectiveness.

In turn, such forecasts should trigger the acquisition of new main equipment, new training requirements and the development of suitable doctrine to manage the maintenance of an effective force design.

7. THE HIGH COMMAND

It is necessary for control purposes that at the High Command, they know to what extent the military strategy, ends, missions and tasks may be supported by the force design. This will enable the High Command to track whether the situation is improving or declining and whether the given policy has the desired effect.

To this end, E^R, E^E, E^M and E^{TF} are applicable control measures. In themselves, they will indicate whether the force design at present is able to support the military strategy inclusive of its ends and ways. Successive measurements will indicate the trend and will enable the forecasting of these measures. In turn, this will enable proactive decision-making.

8. EFFECTIVENESS AS A PERFORMANCE INDICATOR

Effectiveness is a useful performance indicator for management. Unit, Formation and Service outputs become measurable entities and their management's performance agreements may stipulate a quantifiable performance level to be reached.

Whereas the effectiveness levels to be maintained by management is normally an agreed to quantity, it may be necessary to set minimum requirements to ensure combat ready forces during periods of tension. However, when the interdependency of force structure elements are considered, it is clear that higher levels of individual effectiveness be stipulated so as not to affect the dependent force structure elements to the degree that they might not be able to be considered combat ready.

In order to find the required minimum levels to be achieved by all the *n* force design elements that are dependent or interdependent on one another, it is necessary to simultaneously solve the non-linear set of *n* equations where the *i*th equation of the form

$$p_{ii}E_i + \sum_{\substack{j=1 \\ j\neq i}}^{n} p_{ij}E_iE_j \geq e_i \qquad (5.3)$$

and where p_{ij} is the proportion of the effectiveness of the *i*th force design element that is influenced by the effectiveness of the *j*th force design element and e_i is the minimum effectiveness level required for the *i*th force design element. We note that

$$\sum_{j=1}^{n} p_{ij} = 1 \qquad (5.4)$$

and that

$$0 \leq e_i \leq 1 . \qquad (5.5)$$

9. FINAL CONCLUSION

Recall that the Quantified Strategy Model consists of a representation of a military strategy by a ranked tree where the following information is stored at the vertices:

- The relative contribution of any military strategy entity represented by the vertex $\langle \varphi i \rangle$ to its next higher entity represented by the predecessor vertex $\langle \varphi \rangle$, denoted $\upsilon_{\langle \varphi i \rangle}$.

- The actual or real contribution of the vertices $\langle ijklm \rangle$, associated with force design elements, to their respective predecessor vertices $\langle ijkl \rangle$ associated with their respective operating systems, denoted $\rho_{\langle ijklm \rangle}$.

- The effectiveness of force design elements, $E = A_O DC$, are stored on their associated vertices with labels $\langle ijklm \rangle$.

From the information stored on the vertices of the tree, we may, *inter alia*, calculate the following:

- The degree, to which any entity associated with a particular vertex in the tree, contributes to some entity at a higher level of abstraction in the tree, $\tilde{\upsilon}_{\langle \varphi \rangle}$.

- The effectiveness of the force design to

  - operate as an operating system,

  - execute military tasks and missions,

  - achieve the military strategic ends, and to

  - support a military strategy.

After careful and due deliberation, no new intuitions emerged about the model and therefore we consider it to be requisite[6].

This concludes the exposition of the Quantified Strategy Model.

Placetne frates?

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[6] Phillips, L.D., Requisite Decision Modelling, *Journal of the Operations Research Society*, Vol 33, 1982. p. 37.