RESEARCH ON ARCHITECTURE FRAMEWORK MODEL BASED EVALUATION INDEX FOR AVIATION SCIENCE & TECHNOLOGY MANAGEMENT

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Abstract

The aviation Science and Technology (S&T) management activities were analyzed based on the Zackman Framework Model from different stakeholder and different viewpoints, and a structural model for Aviation materiel S&T management with identical core elements was established in order to construct the evaluation framework with five element systems. According to this, a set of evaluation index system comprised with 11 indicators for aviation materiel S&T value oriented was established. Then some aviation institutes were chosen as example, and had been evaluated through data collect and compute using the above evaluation index system.

Keywords: evaluation index system, zackman framework model, science and technology, architecture

1. Introduction

Aviation materiel Science & Technology (S&T) activities play strategic supporting role in the research and development of aviation materiel, which aims to manage basic research, applied research, and/or advanced technology development activities [1]. Usually, defense investment focuses on conducting research to generate scientific knowledge, exploring new technologies, demonstrating the feasibility of technology concepts, so that military users could attain breakthrough warfighting capabilities [2]. Ideally, the funding will result in relevant and feasible technologies that can transition into weapon system programs or go directly to the warfighter in the field, such as the famous X-planes that had demonstrated many technologies (e.g. stealth technology, morphing structure, etc.) adopted in many fighters and bombers . However, with the rapid increasing demand for new high-tech weapon systems, it also faces many challenges such as larger investment, lower outcomes. Hence, how to establish an evaluation index system to evaluate and improve the management effectiveness through promoting the reform and construction is main task and problem at present.

The evaluation of S&T research mostly focuses on programs/projects performance evaluation and organization research and development (R&D) capabilities evaluation rather than research R&D activities evaluation [3-4]. In previous research, an evaluation index system has been established based on Delphi method, and encountered many problems, such as inconsistence of indexes, high sensitivity of index weight, and data singularity, etc. [5]. On the other hand, currently, mature methodology, such as TOGAF, Zackman and DoDAF [6-9], were utilized to construct the enterprise or organization's architecture that could realize the strategic planning of business, capability, application, etc. In these models, the object has been surveyed from multiple dimensions by a matrix method. Aviation materiel S&T activities also involve various R&D activities and different responsibilities, which is similar to the enterprise architecture model.

The architecture model is used to deconstruct and analyze the aviation materiel S&T activities. And a set of quantitative evaluation index system has been established to solve the problems of scientific and systematic deficiencies in the process of evaluation index construction.

2. The Architecture framework for aviation S&T based on Zackman model

2.1 Logic model for Aviation S&T activities

A general logic model for aviation S&T activity often refers to 4 aspects: inputs, process (activities), outputs and effects. All stakeholders participated in the research activities through program/project, as shown in Figure 1.

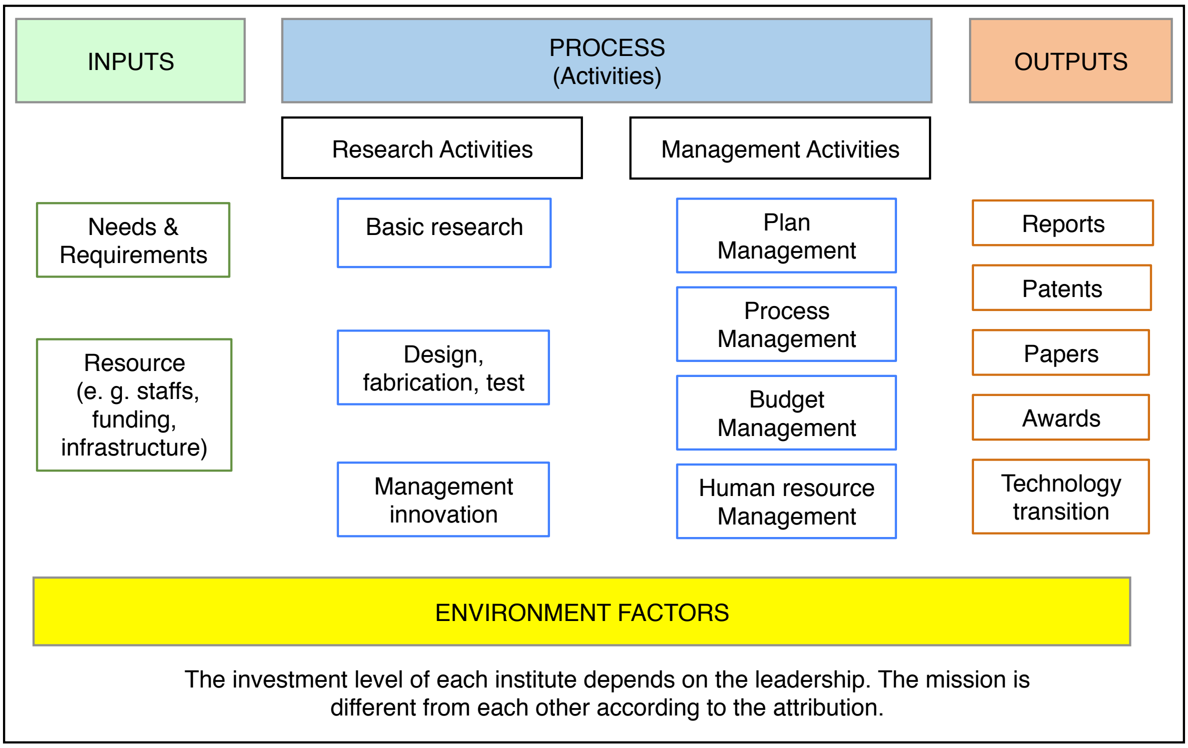

Figure 1 – Logic model for aviation science & technology activities

Taking some institutes for example the need and requirement focus on the whole knowledge required for the weapon systems developed in future 10-20 years. The input phase refers to the contributions necessary to enable the S&T to be implemented (e.g. staff, funding and infrastructure). The process phase refers to the aviation S&T activities such as research and management activities (e.g. plan, budget, etc.). In the output phase, aviation activities are achieving the expected effects/changes in the short, intermediate, and long term. The environment factors include not only macro-environment in nation and micro-environment in institutes, but also the investment level in institutes according to different subordination and attribution.

2.2 The Architecture framework for Aviation S&T activities

The stakeholder in the aviation S&T activities includes researcher and manager from service, industry and institute, which often has different perspectives and consideration. Meanwhile, we usually need to identify the core factors (e.g. data, function, schedule, organization and strategy), analyze the relationship and build an architecture framework in order to evaluate and manage the aviation S&T activities.

The Architecture for aviation S&T activities was established after analysis and definition for each element from sematic, concept, logic, physics, component and function, as shown in Table 2, according to the Zackman framework model that is a two dimensional classification scheme for descriptive representations of an Enterprise [6].

In first dimension, the vision includes multiple roles (e.g. planner, owner, designer, builder) from service, industry, institutes, which define the scope, business model, system model, and technology model of the aviation S&T architecture. Different perspectives are being represented over the process of aviation science and technology development. In second dimension, the viewpoints include data (what), function (how), network (where), people (who), time (when), motivation (why).

Table 1 – Analysis for aviation science & technology activities based on Zackman framework

	Scope (Contextual) Planner	Business model (Conceptual) Owner	System model (Logical) Designer	Technology model (Physical) Builder
What	Critical requirements	Critical technology list	S&T project list	Research and management activities
How	Analysis of materiel requirements	Allocation of human, budget and material resource	Allocation of human, budget and material resource	Design, calculation, analysis, fabrication, test
Where	Nation	Aviation industry	Institute	Laboratory
Who	Service S&T organization	S&T management department (AVIC)	Program manager (Institute)	IPT
When	Milestones	Master schedule	Schedule	Sub-Schedule
Why	Advanced technology capability	Technology roadmap	Project plan implemented	Technology achievements

In comparison with the logic model for aviation science and technology activities, the services focus on materiel requirement and program manager pay more attention to allocation of human, budget and material resource, providing good innovation environment, and process management.

3. Evaluation index system for aviation S&T activities

3.1 Basic elements in evaluation framework

Generally, basic elements in a science and technology evaluation standardly include five aspects: who will implement the evaluation, what will be evaluated, how to conduct the evaluation, and the effectiveness [10]. In this paper, basic elements for aviation S&T evaluation were analyzed, and evaluation framework was built based "five element model", as shown in Figure 2.

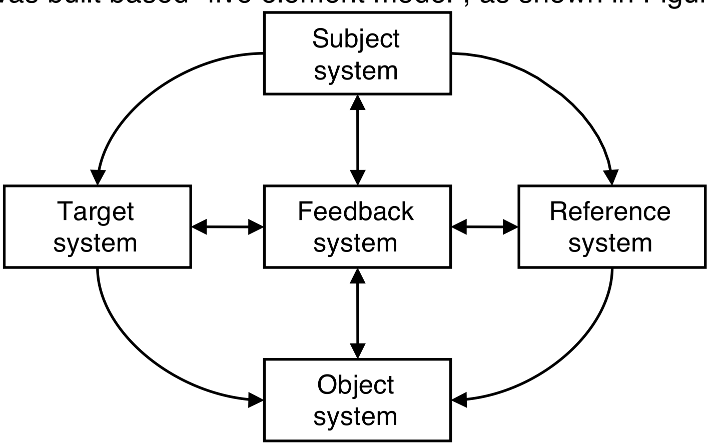

Figure 2 – Evaluation system based on "five-element model"

In the model, subject system is comprised of value subject that represents the whole aviation industry and evaluate subject that independent review team. Also, object system comprises value object that represents performance for aviation S&T activities in each institutes and evaluate object that include all institutes in aviation industry. The target system is the expectation from values subject to values object, or "S&T working mode with optimized structure, sustainable development, well supported to materiel development characteristic". The reference system represents evaluation index system that provides criteria for evaluation. The feedback mechanism from output to evaluation object is established in the feedback system.

3.2 Evaluation index system

The evaluation index system is built according to the logic model in previous chapter. It reflects 11 sub-indicators in four subsystems such as leadership, management, environment and performance, as shown in Figure 3.

Table 2 – Evaluate index for aviation science & technology management

<table>
<tr><th>Target layer (T)</th><th>Evaluation indicator (E)</th><th>Criteria (C)</th></tr>
<tr><td rowspan="3">1 Leadership</td><td>1 Organization</td><td>1 Affiliation of S&T department
2 Administration and technology leader in S&T
3 S&T meeting frequency</td></tr>
<tr><td>2 Policy</td><td>4 quality and quantity of rules and regulations
5 execution of rules and regulations</td></tr>
<tr><td>3 Planning</td><td>6 planning make
7 planning execution</td></tr>
<tr><td rowspan="3">2 Management</td><td>4 Management practice</td><td>8 contract management
9 plan management
10 process management
11 data management</td></tr>
<tr><td>5 Budget management</td><td>12 budget implantation efficiency
13 outsourcing contract ratio</td></tr>
<tr><td>6 Management tools</td><td>14 technology readiness level
15 work breakdown structure
16 technology roadmap
17 knowledge management</td></tr>
<tr><td rowspan="3">3 Environment</td><td>7 Staff</td><td>18 quality of S&T employees
19 quantity of S&T employees</td></tr>
<tr><td>8 Funding</td><td>20 investment in S&T</td></tr>
<tr><td>9 Infrastructure</td><td>21 laboratory (quantity, operation)
22 innovation center (quantity, operation)
23 academic journal (quantity, quality)</td></tr>
<tr><td rowspan="2">4 Performance</td><td>10 Competiveness</td><td>24 investment resource of programs/projects
25 funding of programs/projects</td></tr>
<tr><td>11 Effectiveness</td><td>26 patent (quantity, quality, technology transition ratio)
27 report quantity
28 paper (quantity, impact factor, citation)
29 reward</td></tr>
</table>

Organization, policy and planning are three secondary indicators under leadership. Organization covers 4 indicators such as department, leader, meeting, etc. Policy refer to 3 indicators includes the readiness and execution of rules and regulations. Planning refer to indicators about the make and execution of S&T planning. Management comprises three secondary indicators: management practice, budget management and management tools. Management practice covers 4 indicators such as contract management, plan management, process management, and data management. Budget management refers to budget implementation efficiency and outsourcing contract ratio. Management tools refer to technology readiness level, work breakdown structure, and technology roadmap, etc. Staff, funding and infrastructure are three secondary indicators under environment. Staff refers to quality and quantity of research employees. Funding refers to investment in aviation S&T program. Infrastructure refers to 4 indicators such as laboratory, innovation center, and academic journal, etc. The program/project competitiveness and research effectiveness are two secondary indicators under performance. The first indicator refers to the resource and funding of program/project, and the second covers 5 indicators such as patent, report, paper and reward.

4. Calculation method for indicators

4.1 Variables normalization

Firstly, the statistical analysis of 11 indicators shows that the characteristics of various indicators are different. The evaluation value varies with the proportion of the actual data, and there are curve patterns in which the influence of the change of the curve type and the indicator value on the overall water level of things changes gradually. In order to eliminate the influence of measurement units on the original data, the inverse index is converted into positive index, and the index values of different measurement units are transformed into the same dimension values that can be added directly, i.e. the data is normalized through mathematical transformation. Taking the model of indicator "policy" refer to applicability of rules and regulations under leadership as an example, we should consider whether there are rules and regulations, the scope of coverage, as well as the income level, annual promotion, training and other conditions of S&T staff. The calculation formula of the indicator is:

$$E2 = w_1(IL/IL_{max}) + w_2(Ts/Ts_{max}) + w_3(Ps/Ps_{max}) \quad (1)$$

Here, *E2* refer to indictor policy, *IL* refer to income level of S&T employees, *Ts* refer to training frequency of S&T employees, and *Ps* refer to promotion frequency of S&T employees. And *w1*, *w2*, and *w3* refer to the weights.

4.2 Piecewise function method

After statistical analysis of some data samples, it is found that most data samples are in the state of normal distribution. According to the characteristics of target orientation, an interval assignment method based on Gaussian distribution is proposed to design the calculation model. Firstly, the data distribution range of the data samples is divided into several internals. Combined with practical experience, the Delphi method is used for different intervals Line subjective assignment. Taking the calculation model of indicator funding as an example, the equation is:

$$E8 = \begin{cases} 1, \ a > 125\% \\ 0.8 * a, \ \ 100\% < a < 125\% \\ (a-1) * \frac{0.8}{0.6}, 40\% < a < 100\% \\ 0, \ a < 40\% \end{cases} \qquad a = GF/GF_{avg} \quad (2)$$

Here, *E8* refer to indicator funding, *GF* refer to S&T funding growth, *a* refer to the proportion of funding growth rate to average growth rate. In data samples, the funding growth rate is different in each stage. When funding growth rate is less than average growth rate, the indicator value changes greatly, otherwise, the indicator value changes linearly. And when the proportion (*a*) is greater than 25%, the evaluation value changes less.

4.3 Weighted average evaluation based on ranking method and normal distribution method

Ranking method refers to replace the data by their rank and convert to evaluation value. And normal distribution method refers to examine the relative distance between the actual value and the optimal value. Here, Firstly, ranking actual value in each indicator separately (e.g. funding per employs, patent coefficient, report coefficient), and converting the ranks to evaluation values, finally, calculating the indicator by weighted average method. Taking the calculation model of indicator effectiveness as an example, this indicator mainly assesses funding, patent, report, etc. the equation is:

$$E11=w1|1-Fu/Fu_{avg}|+w2(Pa/Pa_{max})+w3(Re/Re_{max})+w4(Pc/Pc_{avg}) \quad (3)$$

Here, *E11* refers to indicator effectiveness, *Fu* refers to funding per employee, *Pa* refers to patent coefficient, *Re* refers to report coefficient, *Pc* refers to paper coefficient.

5. Case study

Taking some institutes for example, the scores for 11 indicators were attained after data collecting, verification, calculation, and output analysis, as shown in table 2. Here, all scores have been normalized to numerical value between 0 and 1 in order to analyze the overall distribution.

Table 3 – Evaluation Result for Aviation Science & Technology of Some Institutes

Indicator \ Institute	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8	No.9
Organization	0.69	0.75	0.84	0.63	0.50	0.53	0.43	0.84	0.84
Policy	0.83	0.92	0.70	0.68	0.74	0.86	0.89	0.70	0.73
Planning	0.66	0.80	0.65	0.74	0.69	0.58	0.66	0.66	0.73
Management practice	0.87	0.70	1.00	0.87	0.90	0.94	0.99	0.49	0.83
Budget management	0.83	0.82	1.00	0.93	0.96	0.97	0.72	0.82	0.96
Management tools	0.19	0.34	0.34	0.38	0.38	0.50	0.53	0.56	0.63
Staff	0.47	0.79	0.66	0.57	0.72	0.59	0.51	0.84	0.77
Funding	0.37	0.60	0.62	0.72	0.69	0.59	0.75	0.46	0.85
Infrastructure	0.11	0.48	0.72	0	0.34	0.24	0.33	0.29	0.5
Competitiveness	0.24	0.34	0.60	0.10	0.21	0.22	0.46	0.29	0.24
Effectiveness	0.22	0.31	0.41	0.14	0.28	0.53	0.21	0.23	0.56

The average rate for pass and average score were chosen to analyze the overall distribution, as shown in table 3. In all 11 indicators, “policy”, “planning”, “budget management”, “management practice” got high scores, both in average rate for pass and average score, i.e. all institutes provide strong leadership and better management in aviation S&T activities. In the other hand, “management tools” and “effectives” got worse score, i.e. the performance needs to improve in order to get better outcomes.

Table 4 – The numeric results for evaluation indicators

No.	Indicator Name	Average rate for pass	Average score
1	Organization	66.67%	67.22%
2	Policy	100.00%	78.32%
3	Planning	100.00%	68.55%
4	Management practice	88.89%	84.48%
5	Budget management	100.00%	89.04%
6	Management tools	11.11%	42.71%
7	Staff	55.56%	65.71%
8	Funding	66.67%	62.65%
9	Infrastructure	11.11%	33.57%

10	Competition	11.11%	30.02%
11	Effectives	0.00%	32.17%

The above results analysis focus on the overall distribution, the following analyze results is take No.1 institute for example, as shown in Fig.4.

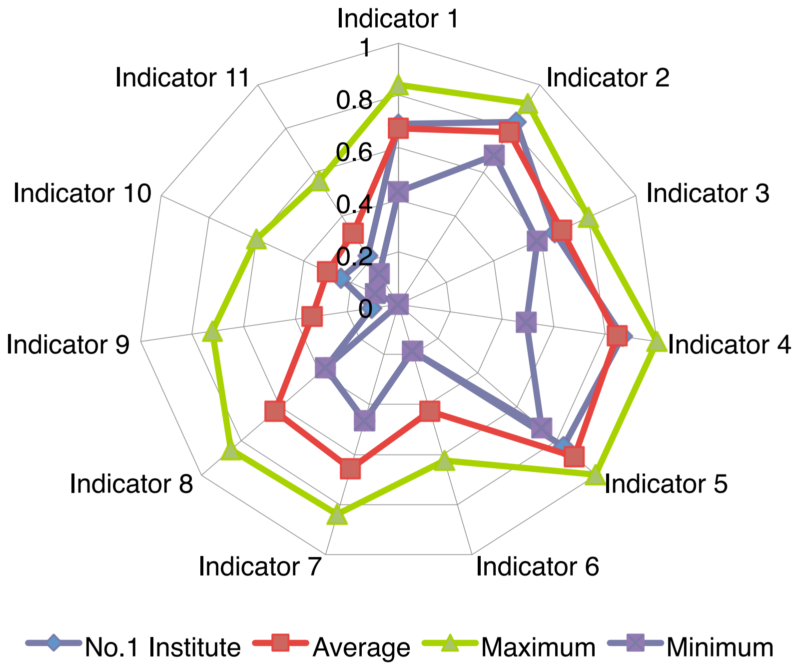

Figure 3 – The numeric results of No.1 institute

The strength and weakness in aviation S&T activities were found through the evaluation, and the target and orientation for future work were established so that the institute could improve the management level and research outcomes.

6. Conclusions

Through the theory and practice in this paper, the zackman model is feasible for analyze and construct the architecture for aviation science evaluation. The evaluation system comprise of object system, subject system, target system, reference system and feedback system provides an operational evaluation model. And the evaluate index system with 11 indicators under three layer established display good consistency and completeness, which covers the whole factors in aviation S&T activities. Take 9 institutes for example, some case studies show that the evaluate index system display good operation ability and effectiveness.

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8. Copyright Statement

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