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EMPIRICAL STUDY ON OUTSOURCING FACTORS FOR COLLABORATIVE PRODUCT DEVELOPMENT IN AIRCRAFT PROGRAMMES IN INDIA

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ABSTRACT

The objective of this paper is to investigate the impact of factors that contributes to the success of engineering and embedded systems outsourcing in complex product development and to develop an outsourcing framework for collaborative product development in aircraft programmes in India. Based on the review of literature on complex product development and strategic outsourcing, the potential factors that determine the product development outsourcing outcome have been identified. The factors are further validated through a qualitative analysis with the experts in the field with more than 20 years of experience. A survey instrument is developed for data collection to validate the model. An exploratory factor analysis has been done on the data collected during the pilot study phase. An important insight from this study is that the technical factors and process factors play a crucial role in determining the outsourcing outcome in the product development in aircraft industry. There is a significant variation in the outcomes depending on the discipline. The implementation factors are more relational in nature with respect to R and D labs / PSUs and are more contractual in nature when it comes to private industries. The study has limitations of looking into the product development outsourcing outcome of only one programme and from the client perspective alone.

Keywords: collaborative product development, aircraft programs, outsourcing, outsourcing outcome, embedded and engineering systems, complex engineering systems, technology development, aerospace.

INTRODUCTION

Aerospace industry worldwide is changing rapidly from a vertical integration strategy [1] to a global product development paradigm [2]. Across the world, aerospace industry is concentrated in *clusters* in USA, Europe, Canada, Brazil, and Japan and recently in China. The aircraft industry is structured in multi-tiers, with the tier-1 organizations doing the overall program management and the aircraft integration tasks, tier-2 organisations working on major assemblies and systems/subsystems and the tier-3 organisations working on sub-assemblies and component level design / manufacturing. In the last decade, the shift from domestic outsourcing to global product development has been driven by the cost reduction strategy and access to the market in the new economies and regions [3].

In India, the aerospace R and D and industry cluster is concentrated around Bangalore, Hyderabad, Pune and Trivandrum and this sector related product development is mostly under the ambit of the government institutions. Most of the knowledge, know-how and talents are in the public sector enterprises. Most of these organizations are plagued by the severe problems.

- Acute manpower crunch as there is a ceiling by the government
- Frequent time overruns and slippages in the programs that are of strategic importance
- The cost escalation because of time overruns
- Denial of critical technology from the developed nations

While the US / European aerospace monoliths / consortia are driven by the quest for cost reduction and new markets under their globalization / new market strategy, Indian aerospace organisations are building strategic alliances, venturing into collaborative product development and outsourcing to meet its technology requirements and the spiralling growth in the new product requirements.

AIRCRAFT INDUSTRY IN INDIA

The Indian aeronautical industry is still at a nascent stage. Hindustan Aeronautical Limited is the main aircraft manufacturer, National Aeronautical Laboratory, Aeronautical Development Establishment and Center for Airborne Systems (CABS) are the three major premier R and D Labs and Aeronautical Development Agency is the nodal program management agency coordinating and integrating the design and development of LCA and its variants in premier academic institutes, DRDO Labs, CSIR Labs, HAL division across the country, other public sector and private sector industries. There are around 500 private vendors who participate in the programs in various domains at different levels.

DEVELOPMENT PROGRAMS

The major aircraft programs that are under various phases are the Light Combat Aircraft (LCA), its Naval variant, LCA MK-2, Advanced Medium Combat Aircraft and the Fifth Generation Fighter Aircraft, Rustom-II, AEWA and the Regional Transport Aircraft. The challenges faced in the developmental programs are

- The products that are being developed are to use the latest generation technologies.
- There is a need to bridge the large technological gap in this field.
- There are a number of technologies that needs to be developed before used in the aircraft products.
- It takes a long lead time to develop these technologies before it reaches the required maturity levels (TRL).
- Technology development has to happen simultaneously with the product development.
- Technologies that are developed have to be assimilated and absorbed by the developmental ecosystem and incorporated into the products.
- Delivery on time to meet the operational requirements of the defense services.
- There is a continual refinement of the products as the technology matures.
- The failure in any of the stages of the programs at the testing may lead to temporary halting / permanent closure of the program. This requires rigorous certification processes.

To meet the above challenges, collaborative product and technology development is a necessity. The outsourcing of the development activities to various organizations that have expertise in their domain and integrating them into the final product is a major techno-managerial problem faced by the program management organizations.

LITERATURE REVIEW

The area of outsourcing has been well researched for over thirty years [4]. Outsourcing has its beginning in the erstwhile make-buy decision in the manufacturing industries. The outsourcing academic literature is abundant in the field of IT services. The IT off shoring literature is a well researched topic that has kept pace with the practice [5]. However, outsourcing in areas such as collaborative product development in India has received very little attention from researchers. Even there, the focus has been mainly in the area of market research to present the case of India as an outsourcing destination to MNCs.

The theoretical foundations for sourcing are detailed in [6] and as per the author they are "institutional theory, resource dependence theory, network theory, systems theory, resource/knowledge based views of the firm, transaction cost economics, agency theory, strategic choice theory, socio-cognitive theory and critical theory".

The literature in the area of outsourcing decision, management and governance, implementation and the outcome of the outsourcing are reviewed in detail in the aerospace and allied domains.

OUTSOURCING DECISION

The decision as to what to outsource and to whom to outsource is a well-researched topic in a general context. There are many conceptual frameworks that inform the outsourcing decision. Core competence theory by Prahald [7] argues that all activities except the core competence is established are candidates for outsourcing. The resource-based view and knowledge based views theories [8] emphasizes on the need for resources that are unique and valuable. The skilled resources external to the organisation if exploited appropriately are a major source of competitive advantage. Various decision making methodologies using AHP, ANP, Fuzzy ANP, DEA and Integer programming techniques [9] has been applied in outsourcing decision framework.

The important factors in the domain of complex engineering systems towards outsourcing are strategy, functionality, design complexity and the vendor capability. The decision is influenced by the strategic intent. The various strategies are cost reduction, technology acquisition, flexibility, cycle time reduction, manpower deployment etc. The functional characteristics and the complexity of the activity to be outsourced is major determinant. The transaction cost theory views asset specificity, uncertainty and the frequency are three major factors that affect the transaction cost involved. The modularity and its effect on outsourcing have been studied in the automotive industry [10] very well. The technical and process capability of the vendor in terms of the domain expertise, development process, related environmental testing and certification capabilities are a key factor. Previous experience in the offshore engineering services to the established aircraft majors will also be a key determinant. Though there is extensive research on the outsourcing decision, the industry specific focus is rare in the literature.

CONTRACTUAL GOVERNANCE

Once a decision is taken to outsource an activity, then it is the governance mechanism that determines the success. Two major types of governance mechanisms are contractual and relational. Contractual governance refers to all the hard factors that bind both the parties to the detailed technical requirement specifications, schedules and escalation mechanisms. The critical reviews or stage-gates in the development projects are defined and the composition of the expert team to review the progress is also defined. Though it is necessary and required to specify all performance measures in the contract, it is virtually impossible to specify all emergent situations in the same. The main factors that are considered here are the contract details - service levels, performance warranties, penalties for non-performance, schedules etc, contract type - partnership based contracts, arms-length contract, fixed cost, men and material, service fee based etc and duration - short term contracts and long term contracts. Contractual governance [11] factors are the main determinants of project success in outsourcing to the private organisations. However, empirical research in the areas contractual governance is very rare.

RELATIONAL GOVERNANCE

The relational governance mechanism plays a very important role in the complex product development scenarios where a lot of interaction has to happen in both directions. It covers the soft issues such as trust,

cooperation, mutual dependence, openness, knowledge transfer and informal communication. Trust has been studied in [12] and different types of trust as studied by Shaberwal are "calculus-based trust that is rooted in rewards and punishments associated with a particular project, knowledge-based trust that depends on the two parties knowing each other well, identification-based trust that follows from the two parties identifying with each other's goals, and performance based trust that depends on early project successes". Knowledge transfer with the supplier in aerospace product engineering has been studied in [13]. The research question as to what is the mechanism for knowledge governance in project based organizations (PBOs) has been studied in [14] and the author concludes that "Formal governance mechanisms are less effective than relational ones for knowledge governance practices in PBOs and Executives' relational governance impacts knowledge exploitation in PBOs".

TECHNICAL IMPLEMENTATION

The implementation related technical and process factors that are of importance to product development are [15].

- Systems engineering processes at the supplier and client end.
- Process / methods and tools to track and report performance versus goals.
- Periodic reviews such as SRR, PDR, CDR etc.
- Formal process for corrective action - Defect investigation teams etc.
- Effective information flow to execute the contractual requirements and SLAs to be achieved.
- Formal processes to transition to outsourced model
- Roles and responsibilities to the right people from both the parties to manage the relationship.
- Process, methods and tools for product lifecycle management.
- Collaborative tools that enable instant interaction and the remote teams.
- Collocation of the team at the client premises to address the security related issues.
- Environment that is open so that failures can be discussed and bring out issues early.
- Codification of knowledge available and sharing it with the team members in terms of technical memos, reports etc.

OUTSOURCING OUTCOME

The outsourcing outcomes anticipated or the expected benefits and the likely negative outcomes or outsourcing risks are a well researched area [16]. The positive outcomes are cost reduction, reduction in time to develop, technology acquisition, augmented skills / resources, reduction in capital expenditure, cycle time reduction, improved employee morale and satisfaction, avoid burnouts and focus on core competence.

The negative outcomes of the outsourcing [17] [18] are the risks - skill erosion, loss of knowledge, creation of new competitors, hidden costs, inflexibility, conflict of interest and security issues. The delay in the launch of A380 / Boeing 787 is attributed to the delay from the partners.

RESEARCH GAP

The research gaps identified in the literature review are:

The outsourcing phenomenon has been explored as R and D outsourcing, technology outsourcing, value chain outsourcing and NPD outsourcing.

- Many of the studies are conducted in the context of manufacturing / product development outsourcing from MNC firms to global firms / developing countries i.e. there is a gap in the study on domestic outsourcing in the Indian context.
- IT outsourcing has gained more focus in the academic literature that too mainly from the off-shoring perspective. Product development outsourcing is a recent phenomenon in Indian aerospace industry and is not reported in the literature.
- There is significant amount of market research conducted regarding opportunities for aerospace companies to invest in India and the off-shoring of engineering services primarily from the cost economies advantage and the abundant engineering skills available as a spinoff of the IT offshoring success.

RESEARCH QUESTIONS

This paper is focused on the specific industry segment - Indian aircraft development. The research questions are:

1. What are the factors that determine the engineering and embedded systems product development outsourcing?
2. What is the impact of the contractual and relational governance factors on the outsourcing outcome?
3. What is the impact of the implementation factors on the outsourcing outcome?

RESEARCH METHODOLOGY

A qualitative analysis of an aircraft programme was undertaken along with the literature review to arrive at the conceptual framework. The research constructs and the operational definition of the variables are based on the literature review and the in-depth interviews conducted with the experts in the field of aeronautics with more than 20 years of experience. A survey methodology has been chosen to validate the research hypotheses.

CONCEPTUAL FRAMEWORK

The conceptual framework of the outsourcing outcome in the product development area in the aerospace projects is given in Figure-1. The hypotheses that are to be validated are:

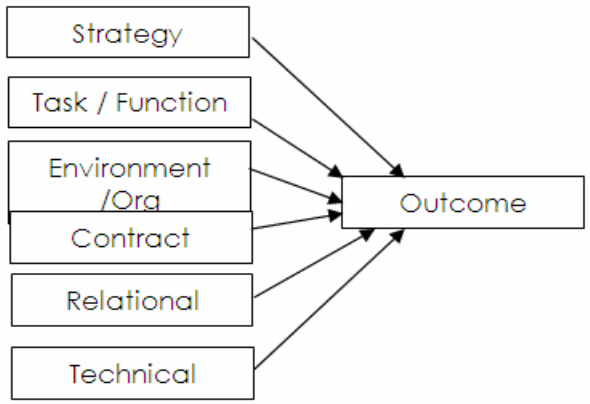

Figure-1. Conceptual framework.

HYPOTHESIS

RQ1: What are the factors that determine product development outsourcing?

- H11 Acquisition of critical knowledge, technology and augmentation of skilled resources are the main reasons for outsourcing
- H12 Cost savings is not one of the main determinants of outsourcing in A and D sector in India unlike the MNC firms.
- H13 The level and depth of outsourcing depends on the discipline, the complexity and uncertainty involved in that area of work
- H14 The urgency of the operational need of the system and the tight schedule positively influences the outsourcing decision.
- H15 The skill availability in the external environment positively influences the outsourcing decision

RQ2: What is the impact of contractual and governance factors on the outcome?

- H21 The contract attributes such as size, duration and schedules influence the outsourcing outcome.
- H22 The relational attributes are more influential than the contractual attributes in determining the outcome.
- H23 Knowledge transfer to and from the outsourcing vendor positively influences the outsourcing outcome.
- H24 Relationship building with the strategic vendors contributes positively to the outcome.

RQ3: What is the impact of implementation factors that influence the outcome?

- H31 Effective Systems engineering process deployment influences the outcome positively.
- H32 Collaborative tools significantly affects the problem resolution cycle and contributes positively to the outcome
- H33 Product lifecycle management processes, methods and tools usage positively influences the outcome
- H34 Collocation of the development team at the client premises positively impacts the outcome.
- H35 Coordination mechanisms should be based on the product modularity, complexity and technological uncertainty and suppliers capability for better outcomes.

RESEARCH CONSTRUCTS

The research constructs that are identified and the operational measures are as follows:

Table-1. Outsourcing constructs.

No.	Construct	Operational Items
1.	Strategy	Core competence
2.		Critical knowledge
3.		Augment resources
4.		Access technology
5.		Flexibility
6.		Cost control
7.		Quality impact
8.	Task/function	Complexity
9.		Integration
10.		Asset specificity
11.		Structured/ codification
12.		Employee-impact
13.		Uniqueness
14.	Technical	Infrastructure
15.		Prototypes
16.		Design reviews
17.		Design attributes
18.		Systems Engg
19.		Config Mgmt
20.		Progress reviews
21.		Tools deployment
22.		Project mgmt.
23.		Knowledge mgmt
24.	Environment	Skill availability
25.		Legal issues
26.		Competitor action
27.		Conflict of interest
28.		Uncertainty
29.	Organizational env	Preference-of-managers
30.		Top-mgmt-commitment
31.		Teaming
32.		Professional growth
33.		Professional mgrs
34.		Psychological safety
35.		Technology-updates
36.		Key-personnel
37.	Contract	Pre-contract activities
38.		Type
39.		Size
40.		Duration
41.		Preciseness

42.		Completeness
43.		Balance
44.	Relationship	Pre-project prep
45.		Trust
46.		Communication
47.		Sharing
48.		Mutual dependence
49.		Cooperation
50.	Outcome	Cost control
51.		Delivery time
52.		Scope completion
53.		Technology
54.		New programs
55.		Core competence
56.		Capability augmentation
57.		Spin offs
58.		Regulatory approval
59.		Cycle time reduction
60.		Team satisfaction
61.		Skill development
62.		Avoid burnout
63.		Customer satisfaction

QUANTITATIVE ANALYSIS

The conceptual framework developed during the qualitative analysis has to be validated thru empirical study. The survey methodology was adopted. A survey instruments was developed for data collection from the stakeholders. A pilot study was conducted using the survey instrument and the instrument was validated. Convenience sampling is to be used for drawing samples from organizations which are outsourcing product development activities in aerospace sector. Scientists / Managers with a minimum of five years of experience are to be included in the study as there is a need for employees to have experienced in the process of outsourcing order to be able to respond to the survey.

PILOT STUDY DETAILS AND ANALYSIS

A pilot study was conducted with 45 respondents to test scale reliabilities.

Table-2. Cronbach's coefficient – alpha.

Variable	Items	Cronbach's alpha
Strategy	7	0.626
Task / function	6	0.80
Environment	12	0.73
Contract	7	0.71
Relationship	6	0.81
Technical	10	0.722
Outcome	14	0.828

Multicollinearity can have several harmful effects especially when interpreting the results. Hence all the independent variables are checked for multicollinearity. If the VIF value is larger than 10 or the tolerance value is less than 0.10, one can assume the existence of multicollinearity. As none of the independent variables have crossed these threshold limits as seen in Table-3, it can be concluded that there is no multicollinearity among the independent variables.

Table-3. Collinearity diagnostics.

Predictor variables	Collinearity statistics	
	Tolerance	VIF
STRATEGY	.908	1.101
TASK-FUNCT	.522	1.917
ENVIRONMENT	.279	3.583
TECHNICAL	.822	1.217
CONTRACT	.342	2.124
RELATIONSHIP	.876	3.345

Regression analysis

The model summary and the model diagnostics of the multiple regression analysis are shown in the Tables given below.

Table-4. Model summary- multiple regression analysis predicting outsourcing outcome.

Model	R	R Square	Adjusted R Square	F value
1	.549(a)	.301	.215	4.366**

a Predictors: as given in Table-3
** refers to significance at 0.05 level

Table-5. Model diagnostics- multiple regression analysis predicting outsourcing outcome

	Independent variables	Std B coeff	t-value	Hypothesis support
1	Strategy	.139	1.817	Partial
2	Task / function	.337	2.144*	Supported
3	Environment	.285	3.213*	Supported
4	Contract	.516	3.690**	Supported
5	Relationship	.161	.112	Supported
6	Technical	.098	1.817	Supported

* refers to significance at 0.01 level
** refers to significance at 0.05 level

FINDINGS

The hypotheses related to the factors that determine outsourcing H11, H12, H15 and dH15 are supported. Cost savings is not the determinant in product

development outsourcing. The hypotheses related to the factors of the contracting and relational governance H21, H22, H23 and H24 are supported and plays a moderate role. The hypotheses related to the implementation factors - H31, H32, H33 and H34 are strongly supported and play a vital role in determining outsourcing outcome. The technical implementation factors have a significant impact on the outcome.

CONCLUSIONS

This study is the first of its kind to analyze the outsourcing factors that contribute to the success of the projects in A and D sector in India. The study though at an early stage, point to the fact that outsourcing is a necessity in the aerospace and defence sector. The major determinants of the outsourcing are the product development strategy, the product / technological complexity of the task and the stakeholder's interest. The outcome is determined mainly by the relational governance mechanism and the effectiveness with which knowledge is shared between the clients and providers. The implementation mechanisms - the technical processes, methods and tools plays a determining role in the outcome.

PRACTICAL IMPLICATIONS

The practical implications of this study are

Outsourcing should be pursued as a collaborative product development strategy at the top management level rather than as a way to seek solution to few of the technical problems.

There should a holistic approach considering the task at hand, technology maturity level available in the external organizations so that the scare scientific resources can be channelized into more challenging problems.

The A and D sector firms should build focused competencies on the contractual management, relationship building mechanism, effective project management and knowledge management skills in their organizations.

A product development ecosystem in the high technology areas will provides opportunities for the private industry to participate in the global engineering services outsourcing in the higher in the value chain.

LIMITATIONS

Only a pilot study has been conducted from the perspective of the outsourcing client. A full-fledged field study with a larger sampling in the aerospace and defence sector has to be undertaken as a continuance of this research work. The perspective of outsourcing client is only considered in this present paper.

FURTHER WORK

The perspective of the outsourcing providers towards outsourcing success can be an extension of the present work. Similar study can be undertaken to cover other industry segments where outsourcing will unleash the product development potential and there by contribute to the national growth. Also, research studies on the impact of the domestic outsourcing on the engineering services offshoring to India will be of major interest to the global service providers.

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