Implementing Multi-Organisational R & D Contracts through Multi-Organisational Matrix Structures in Large High Technology Projects

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Specialised R&D organisations operating in areas like astronomy, space or defence need to develop large high technology devices like radio telescopes or satellite earth stations. Such devices require a high level of R&D expertise in a diverse range of technology areas that are neither available nor viable to develop internally within the specialised R&D organisation. A radio telescope, for example, requires sophisticated design expertise and equipment in mechanical, civil, electronic and telecommunication engineering apart from expertise in radio astronomy. This vast range of expertise is normally not available within the radio astronomy research organisation nor within any single other R&D organisation. The specialised R&D organisation therefore has to contract a number of equipment suppliers as well as complementary R&D organisations to design different components of the single large R&D project such as setting up a new radio telescope. Design integration is provided by mutual consultation as no single organisation has the complete R&D "blueprint" for the large high technology project. This article presents a disguised case in which four organisations – a small scale private high-tech firm, two large public sector high tech firms and a technology university were contracted directly or indirectly to work with a specialised government R&D organisation in India on such a large high technology project. Since such projects are usually one of a kind, the contracted organisations incurred considerable developmental costs that could not be amortised to future projects. Initial agreed contract terms that were found inadequate during the project could not be easily modified within the constraints of the specialised government R&D organisation. However the opportunity to learn from the other high technology organisations and the pride of being associated with a nationally important project generated considerable interest and encouraged the involvement of the contracted firms and universities even beyond the contractual or "business" terms initially proposed and agreed. The large high technology project was implemented through a unique multi-organisational matrix structure where dual and even triad reporting relationships existed on both technical and administrative matters, within and across the contracted organisations. Positive relations and mutual forbearance among project managers across the highly heterogeneous organisations helped in the complex and iterative technical integration process and facilitated inter-organisational learning. The article explores the general costs and benefits for participating organisations and the unique co-ordination, integration and adaptation mechanisms required for initiating and implementing such multi-organisational R&D contracts within complex multi-organisational matrix structures for large high technology projects.

Introduction

Strategic alliances between organisations for R&D, both pure and applied, is a topic of considerable research interest (Farr and Fisher, 1992; Forrest and Martin, 1992; Hladik, 1988; Ouchi and Bolton, 1988; McDonald and Geiser, 1985), both from the field of inter-organisational research (see Borys and Jemison, 1989; Oliver, 1990; Ring and Van de Ven for structuring reviews) and from the field of R&D. Joint R&D has largely been studied between competing firms as the area of collaboration within competition evokes considerable interest e.g. research consortia (Ouchi and Bolton, 1988; Forrest and Martin, 1992).

Not-for-profit technological R&D institutions depend on industry for both the generation of researchable problems as well as the transfer and commercial application of the new technology they develop. The industry in turn often relies on such R&D institutions for solving their technological problems and generating new technology. In industries facing constant technological change, firms maintain enduring strategic relationships with R&D institutions for mutual learning. For smaller firms facing rapid technological changes, such links are critical, leading to considerable effort by the firm in building, maintaining and nurturing them.

R&D institutions that find it unviable to maintain internally the entire production or construction machinery and infrastructure as well as manpower required for building either prototypes or final products (like NASA for spacecrafts) subcontract these to the industry. Similarly even large firms with R&D laboratories which either lack or find it unviable to maintain the highly qualified manpower or expensive equipment required for certain parts of their R&D programs subcontract them to R&D institutions (Prabhu, 1999).

Such links are basically symbiotic in nature. The primary expertise in the R&D effort lies within a single organisation - the R&D institution or laboratory, which carries out the developmental work and or co-ordinates the subcontracted work in other organisations. It depends more on the production expertise of the other organisations rather than on their R&D expertise. The inter-organisational link is primarily for information gathering and for refining the developed technology. Under such arrangements, the R&D institution prepares the basic "blue print" for the project which the production units, both internal and external, follow and implement, returning only for clarifications and to report success or failure (Prabhu, 1997). The R&D institution in such cases is able to effectively isolate its core technology (Thompson, 1967), its developmental activity, from its boundary spanning activities. As a R&D organisation by the very nature of its task (Gunz and Pearson, 1977) needs to be organised and managed differently from other activities, such isolation is, to an extent desirable.

A different situation exists when the R&D institution by itself cannot produce a basic "blue print" for the R&D project. In other words, the core R&D expertise required by the high technology developmental project is spread over a number of different organisations – each organisation has different and complementary expertise. These "complementary" organisations may be universities, public or private sector firms both large and small. To implement such developmental projects, these heterogeneous organisations have to necessarily work together for the planning, designing and implementation of the project.

The structural response to such a requirement would be for each participating organisation to create its own project group for deputation to the project. The combination of these project groups comprises the temporary multi-organisational project organisation. This project organisation would typically have a co-ordinator or project head from each organisation representing the organisation in a co-ordination committee with one member assuming the role of a central co-ordinator. The participating organisations may have internal organisational structures varying from functional to matrix to project structures. But considering the highly complex nature of the R&D tasks which typically requires high integration for short project duration coupled with usual functional expertise development, we may expect to find a predominance of matrix structures, over either functional or project structures, especially in the larger organisations.

A matrix structure has "cross functional organisational overlays that create multiple lines of authority and that places people in teams to work on tasks for finite periods of time" (Ford and Randolph, 1992). To the extent that multi-organisational structures fit this definition, we may refer to them as multi-organisational matrix structures. Project implementation through multi-organisational matrix structures made of heterogeneous organisations displays unique and idiosyncratic features. A conceptualisation of such structures in the context of large high technology R&D projects is the focus of this paper. Broader strategic implications for multi-organisational co-operative projects in general, and large high technology R&D projects in particular are developed along with policy requirements for encouraging co-operative R&D among heterogeneous organisations.

Structure of the Paper

After presenting basic case data, the paper first explores the strategic costs and benefits for the participating organisations, and the motivation driving each of them towards participating in the co-operative development effort. It then examines the nature of the task - the large high technology R&D project itself - which guides and imposes constraints on the structure and processes of implementation. Next it enumerates critical resource issues and the mechanisms developed to cope with them. Further it explains the logic of the organisation structural solution and the systems developed to manage it. It then considers co-ordination, leadership and culture issues in this context and ends with managerial and policy implications. Throughout the paper, case data and analysis is presented simultaneously and case vignettes are used for drawing concepts and implications. The paper being exploratory in nature, with a low empirical base, retains tentativeness. It is an attempt to draw attention of researchers and practitioners to this multi-organisational matrix form and the implementation issues that emerge from it as it is a potential area for future research.

Organisation Structure for Multi-Organisational R&D

High complexity and uncertainty characterise R&D work both within and across organisations. Balancing functional specialisation with project integration in a pragmatic manner is essential for success in R&D projects. The nature of the task imposes several requirements for the organisational structure for R&D. Gunz and Pearson (1977) provide the following requirements. The structure must mobilise resources to meet new work goals, combine organisation wide tacit knowledge and technology preventing over specialised thinking, set up new communication networks for each new project, be compatible with larger organisational systems, yet buffer the R&D units from the other parts of the organisation. Further it must allocate efficiently and harmoniously common resources and facilities, ensure specialised skills and knowledge are developed and maintained, and allow for smooth and efficient transfer of R&D output to production.

The above features and requirements are typical for single organisations where R&D is an activity of one subunit, but they are largely true for R&D organisations and multi-organisational R&D consortia efforts, except possibly in the requirements of buffering and compatibility. Apart from these requirements, multi-organisational R&D structures should also enable (a) matching and balancing of skills, knowledge and hierarchical levels across participating organisations, (b) preservation of individual organisation autonomy and secrecy if required without hampering the joint R&D effort, (c) co-ordination mechanisms across organisations with lateral communication at lower levels and (d) the emergence of leaders with respect across participating organisations. Since the use of administrative fiat is difficult, if not impossible, across organisations, there is need for the leadership to (a) develop a collaborative culture with sharing of relevant information, (b) resolve inter-organisational problems and personal anxieties of participating members, (c) manage the delicate task of co-ordinating effectively a set of highly qualified professionals with vastly different disciplinary, organisational, experiential and cultural backgrounds, within organisational norms and strategic imperatives. These requirements are discussed in the multi-organisational project case that follows.

Project

We now describe and discuss a disguised case of a multi-organisational joint research, design, development, and construction project for setting up a large high technology telecommunication workstation. Each telecommunication workstation needs a unique design depending on location environmental factors, its application area and its utilisation norms. The telecommunication workstation development project requires multi-disciplinary skills as it has complex mechanical, electromechanical, electronic and civil subsystems that need to be integrated effectively. Each of these subsystems requires a different set of engineering and technological skills of a highly specialised level. No single organisation in India has the capability and facility to design and build such a complex telecommunication workstation independently.

The organisations participating in the project were A: a private small scale mechanical device manufacturing firm; B: a public sector firm with expertise in electromechanical devices; C: another public sector firm with expertise in electronics; D: a premier engineering research and education institution represented by a multidisciplinary team of engineering professors; E; a government R&D institution involved in telecommunications that co-ordinated the entire project as well as the participating organisations and developed a core device of the telecommunications workstation, and F: a government user organisation in the field of telecommunications which prepared the civil construction for the workstation and eventually used the workstation. A schematic representation of the interfaces between the organisations involved in the project is given in Figure 1. As seen, six largely dissimilar organisations participated in the project, five of whom had unique and complementary technological, and to some extent R&D expertise. All organisations had to be involved at all stages in the project, from initial design to eventual implementation and commissioning.

Figure 1 about here

E is a premier government research institution. It has indigenously developed several technologies and is at the leading edge in a number of research areas. Its major objective is to develop self-reliance in its technology area using indigenous industrial infrastructure. It is oriented towards developing integrated, applications oriented technology and transferring this technology to the Indian industry, serving as import substitutes for various sectors of the economy. Except for minor parts most of the equipment on a telecommunication workstation were manufactured by local industry. Some components were imported. E was involved in the overall planning and part of the design and development of the station. Earlier E had designed telecommunication workstations for internal use. Since it had expertise in this area, other public telecommunication institutions approached E to build telecommunication workstations for them on a turnkey contract basis. These turnkey projects were handled in a similar way as internal projects, with the overall design, quality assurance, prototype testing, integration and testing/commissioning of minor parts being co-ordinated and partially handled by E scientists/engineers and the subsequent designing, fabrication, manufacture, integration and testing/commissioning of larger parts being handled by the industry. In addition members of the user organisation were involved in the design, construction and testing/commissioning phases of the project both for providing required clearances on quality and usability of the station as well as for being trained in handling the telecommunication workstation.

Strategic Fit: Costs and Benefits of Participation

Each of the organisations participating in the project had their own set of costs and benefits of participating, both perceived and actual, some tangible and others intangible. They also had different priorities. The same project served different strategic purposes in different organisations, some of which are discussed here along with the respective organisation's background to give indications of how strategic fit for the project was achieved. Firm A, a small-scale firm engaged in the design and manufacture of sophisticated antenna systems. Its managing partner is a high technology enthusiast. He has over the years, gained expertise in building high accuracy high quality antenna systems. He has worked on a number of E projects. E often invites him for technical discussions and E scientists acknowledge his contribution. Through his experience and development of expertise in both manufacturing and quality control techniques, as well as due to the lack of competition, he has become quite indispensable for E in their telecommunications projects. He is enthused by the challenge of technically and intellectually stimulating projects, which he knows no one else in the country can handle with his high level of quality and competitive price. Though he has a regular and profitable production line of consumer durable items, he spends most of his time and energy on the more interesting E projects, which are a good learning ground for him to develop new expertise. Further for him the greatest motivator is the respect that he enjoys in E, personal congratulatory messages that he receives on successful project completion and the recognition and the feeling of having made significant contributions. He has also received considerable publicity through E projects.

Firm B and C have both had long associations with E. As public sector units, they were the first approached by E, and they were, within reasonable limits, obliged to meet E's needs. Since the state of art in electronics at E is far ahead of that in the rest of the country, firms B and C found it useful to interact with E scientists/engineers through such projects, though on the other hand, E found technology transfer to B and C difficult due to the same technological "distance". For the engineers of B and C the project was a useful learning experience, compensating somewhat for the low profitability or sometimes loss on the project faced by their firms, due to the small lot size and disruption of their regular production lines. A gain of these two firms was the prestige of being associated with high technology frontier research project with a premier institution like E, which was useful for organisational image building.

For the professors in D, apart from the prestige associated with the project, they found the project interesting and intellectually stimulating, enhancing their own learning and practical experience. Their institute encourages them to take up technical consulting as it helps develop better teachers tuned to practice as well as generates additional income for their institutes. For E, apart from the design aspects, a large part of the developmental work involved in such telecommunications workstation projects does not change substantially from one telecommunication workstation to another. For the scientists/engineers at E these more routine tasks were often uninteresting and with limited learning value. Therefore E as a norm, transfers the technology they develop to the local industry for repetitive work, and reluctantly undertakes such work internally only if the industry is unwilling or incapable of handling it. This policy helps both in the objective of building capabilities in the local industry as well as in leaving research personnel at E free to pursue frontier developmental work. Following this policy a large part of the project was sub-contracted, yet administrative issues and project management took considerable time of the scientists at E, which was a major concern for them. The user personnel at F required considerable training and reorientation to the technology of the telecommunication workstation that was new to them. This took place after the installation, integration and commissioning of the telecommunication workstation.

Interdependence

Since the various segments designed and/or built by different organisations had to be integrated at the telecommunication workstation site, no participating organisation could afford to build its assigned system without adequate and regular consultation with other participating organisations. For example the parameters of the mechanical subsystem determined the design of the electromechanical subsystem and vice versa. The technological nature of the project built in a high degree of interdependence between the participating organisations. Apart from the interdependence in the design function between organisations, the task required considerable trial and error between design and construction. Designs had to be altered to suit available material or components. Further, since each telecommunication workstation was unique, incorporating new technology and innovations, considerable trial and error to fit location characteristics was required. These involved multiple organisations as well as multiple disciplines and technologies. The nature of the task therefore imposed constraints on the design of the structure and functioning of the project organisation.

Organisational Adaptation

All the participating organisations had to partially adapt themselves to accommodate the project constraints and requirements. Since Firm A has been continually involved in such projects, it has developed two distinct divisions, one for telecommunications workstation projects and the other for its consumer durable production line, though the same facilities, equipment and sometimes people were used in both.

Firm B and C are both job shop type production firms and have their own R&D laboratories. They are oriented towards medium production lot sizes of approximately 10 to 50 pieces in a production run. They normally developed a prototype through trial and error; blue printed the design and sent it for production. For the telecommunication workstation project, the lot sizes were very small, between two and three (each telecommunication workstation needs backup equipment), so that building prototypes and blue prints were unviable. They had to directly build the finished product on the production shop floor thus disrupting their normal production lines. To adapt to these requirements, they created small project groups to co-ordinate the project across various functional divisions within the firm as well as across organisations.

The multi-departmental and multidisciplinary team of professors of D interacted largely with Firm A, both individually and collectively. They had assigned a student from D to assist in computations and drawings. They also directly contacted the project director at E, whenever urgent clarifications were required, and their members both within the team and across organisations adopted largely informal modes of working and interacting with other participating organisations.

E has been handling similar telecommunication workstation projects for a number of years and had to make no special adaptation. It has an internal matrix organisational structure, with project organisations being constituted based on the technical and managerial requirements of the project. The user organisation F had to depute a team to negotiate with E, on both the financial and technical aspects. They faced the dilemma of lacking the technical expertise to judge the design parameters proposed by E, yet being in a position where administratively their formal clearance was essential. A second user organisation team (partially overlapping with the first) was deputed to assist and learn during the testing, integration and commissioning stages of the project. Members of the latter team were to take over and operate the completed telecommunication workstation.

Complementary Expertise

Each participating organisation had unique and/or complementary material, technological and human resources that were brought together for the project. Firm A has expertise and equipment for high quality, high accuracy mechanical construction. Specific design expertise on mechanical, structural and civil engineering was provided by professors from D. Firms B and C had the expertise to convert prototypes/designs to production form and worked on designing and developing the electronic and electromechanical components. E developed the overall design parameters based on the requirements of the user organisation. The user organisation F provided the civil construction and housing at site, since E scientists/engineers were unwilling to be involved in the administrative issues of handling a task that did not require their technological expertise.

Multi-organisational Project Organisation Structure

The multi-organisational project organisation structure has evolved over a number of telecommunication workstation projects through a process of continuous feedback. It incorporates both individual organisational strategic requirements as well as project imperatives. At E, a project director who is a senior scientist or senior engineer heads the project group as project director. Other members are scientists from complementary divisions/disciplines as required by the nature of the project. The project director convenes and chairs meetings, both internal and multi-organisational, co-ordinates the members on technical matters and holds primarily responsibility for the project. The project director is assisted by a project manager who handles the administrative functions - preparation of project plans, co-ordination with administrative departments both internal and external, and project logistics. Scientists and engineers at E may be members of more than one project group at a time, since projects are long lasting (two to three years) and workload peaks for different projects at different times. They simultaneously work in their own departments on ongoing research programs.

Firms A, B and C also had a similar matrix organisation with project groups consisting of members who simultaneously had divisional and multiple project responsibilities. Production engineers who co-ordinated both administratively and technically headed these project groups. The scientists in firms B and C acted as internal technical consultants. The professor at D who was handling the largest part of the design co-ordinated the activities of the group of professors. The user project group at F was constituted under the advice of E based on its past experience and had both senior and junior personnel. The overall co-ordination of all these individual organisation project groups was by the project director from E. The multi-organisational project structure was therefore relatively flat but the individual organisation project groups had hierarchies of various degrees.

Communications

Informal communications channels were built both within and across organisations to reduce communication delays. To a large extent, any member of the project group of one organisation could directly contact any other member of the other participating organisations, for urgent clarifications, though at times this caused concern if any changes made were not reported subsequently to the group heads. While A and D, B and C were located in two cities in south India, E and F were located in two cities in north India. E convened meetings at intervals at convenient locations for discussion of progress, planning and design integration between groups. The groups also sought help formally or informally from each other on technical and administrative matters, both during these meetings and subsequently.

Co-ordination

Broadly, project heads in the matrix organisation enjoyed lower administrative and hierarchical powers over their members, compared to the member's parent department or functional head. Project heads therefore had to use their negotiation skills within and across hierarchies to effectively co-ordinate their groups. Individual organisation project heads also had to co-ordinate with other departments like workshops on the technical side and purchase, accounts and administration on the administrative side, both within their organisation and in other participating organisations. Each of these external departments had different ways of functioning. Further, project heads had to co-ordinate and adjust with project heads of concurrent projects, especially when common facilities were simultaneously required for two or more projects or when their members were common and were simultaneously required. Conflicts sometimes arose when members received conflicting directives, and the difficulties were compounded when such directives were received across organisations.

Implementation Issues

Transfers, promotions and turnover of group members increased difficulties of co-ordination, first for the new incumbent to get trained and take over, sometimes unwillingly, the duties and responsibilities on a partially completed project and second, for other members, especially at other locations and organisations, who had to encounter a new contact person. Since relationships within project groups were largely informal, based on mutual trust and friendship, such changes were more difficult to manage. As a result some transferred members continued to be contacted about their projects long after their transfer to other projects and departments.

High degree of specialisation among members made it difficult for them to see the project as a whole, so that some members tended to work at cross-purposes, unable to fully comprehend the work in other specialisations and organisations. Perhaps the greatest difficulty lay at the inter-organisational design to production interface. Designs or prototypes built by one organisation were at times not suitable for production or integration with that built by the other organisation. Designers were at times unaware of the limitations of production facilities in other organisations. It was difficult for designers to write good and adequate documentation and a lot of the information required remained in the designer's mind rather than on paper. This difficulty was further compounded by the fact that the designers and production engineers were in different organisations and subsystem interdependence was not fully understood at the initial stages. The knowledge level of deputed user personnel from F was low and E personnel were sometimes unable or unwilling to bring their knowledge level on par for useful contributions from their side, as doing so took a lot of time. Also senior level deputees from the user side were unwilling to be involved in laboratory-shop-floor type of developmental work and had low interest in working along with engineers/scientists from other organisations who were lower than them in hierarchy.

Suggested Improvements

Project participants made a number of suggestions on improving the project process in such large telecommunication workstation development projects. They stressed on the need for a more enthusiastic and participative culture where everybody was involved and excited about the project. They felt the need for the project leaders to adequately recognise participating organisations efforts to improve upon or develop products and their contribution to the success of the projects. In joint work on projects, they felt that efforts should be made to attach to each other people of equal cadre, age group and expertise level from the participating organisations as this could reduce inhibitions and tensions of working together.

To take care of turnover of people during the project, some suggested that a resource person within the project organisation could be designated for the purpose of training and guiding new personnel. A suggested way of solving the inadequate documentation problem was to have short single page notes of all critical aspects/decisions regarding the project maintained centrally, possibly with the help of a project secretary. Another way is to have at least two persons go through all communications sent or received regarding the project. Further all persons involved in a project could go through all communications regarding the project including a gist of telephone conversations. Project participants felt that this could be time-consuming and counter-productive beyond a point, but all persons involved would know everything about the project status. This would aid involvement and help co-ordination and interaction across groups and participants.

Participants suggested that a practice could be initiated where any person involved in a project, who encounters and solves any implementation problem writes a short (within one page) note containing the problem and solution. For a new comer or a new group implementing such projects, the compiled set of such notes could form a useful guideline, thus building up on past experience. Also, circulation of such notes by each member among other members would aid understanding and co-operation between people of different backgrounds, orientation and organisational loyalties. Another suggestion was that a project implementation plan document, which is as complete and accurate as possible should be jointly prepared and widely circulated among all participants. On the technical side it could contain all the information required by a subsystem manufacturer to make an accurate estimate of costs. The specifications would be at as advanced a stage of calculations, testing and corrections as possible so that post-project report modifications were kept to the minimum. On the administrative and management side, this project plan could contain all details including potential cost escalation. The plan could also include the project organisation chart along with the responsibility areas of each person and their contact information so that direct contact could be made during an emergency. Also each person could have an alternate person mentioned in the plan. In other words, the project plan prepared after approval of the project in principle, would be a single complete and integrated document containing all essential information for all participants and organisations involved in project implementation. In this state, it could act as the single most powerful tool for efficient co-ordination of project implementation.

Participants suggested that there could be more meetings between participating organisations at the working level apart from the ones at top management level, to solve mutual problems face to face. This could lead to better understanding and co-operation among people of diverse disciplines, backgrounds and orientations. Conversion from design drawing to engineering drawing could therefore be a joint effort of both design and production engineers, on an equal footing. To do so participants should be provided sufficient information about each component, its criticalities, its functions and its utilisation in the overall system even if they are not directly involved in its development so that sufficient care can be taken during preparation of production drawing and actual production of the components they are directly developing. Information of quality standards required, physical and environmental interfaces, its integration with other systems and the dual configuration must be known to each participating organisation as they evolve during the project.

Participants suggested that there could be some incentives both financial and non-financial for members contribution to the project, such as publicity through press releases and articles, awards for product development, incentive for early completion and public praise for achievement in project meetings and public forums. Apart from these, participating organisations could make the latest information available to regular participants in other organisations, even outside the duration of projects, through newsletters etc. so that they are aware of new developments and changes in technology in their collaborating organisations.

Implementation problems seem to arise largely out of a lack of effective communication and understanding between members of different specialisation and organisations given the diversity of the participating organisations. Yet the project showed that the excitement of frontier level R&D could often override these and make participants develop an enthusiastic participative culture.

Conclusions

The multi-organisational matrix organisation has arisen out of a combination of heterogeneous organisations due to the complementary nature of their resources, which no single organisation found viable to co-opt. No organisation is capable of using all its resources all the time and co-operative relationships help the collectivity to utilise their resources as well as enhance them by mutual learning. Policy could therefore protect and facilitate such processes. The case shows how widely different types of organisations with widely different organisational strategies, can find a strategic match in a joint co-operative effort; with each having different costs and benefits, in implementing a large high technology project. Multi-organisational matrix structures are precarious (Metcalfe, 1981) and need to sustained and nurtured by strong and understanding leadership as well as a culture of mutual trust between organisations.

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Figure 1

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