Towards total project quality: A gap analysis approach

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Towards total project quality: a gap analysis approach

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This paper presents a critique of existing approaches to the management of projects and the definition of project success, arguing that these are both fragmented and fail to place the client at the centre of the process. In this critique, the paper focuses on quality management, and places the minimization of client surprise at the heart of the assessment of project success. As an alternative, a gap analysis approach, derived from the service quality management literature, is developed which, it is argued, provides a better way of understanding the challenge of managing projects. The model is then applied empirically to the Glaxo project, the largest building project in the UK in recent years. The Glaxo project was remarkably successful, and the lessons can be learned well through the perspective of the gap analysis model. In conclusion the paper concludes that quality on construction projects is a negotiated order, and that design reviews are the principal means by which this order is negotiated.

Keywords: Project management, quality management, gap analysis, client satisfaction, Glaxo

Introduction

> 'You did well, Bernardo, in lying to us about the expense involved in the work.'

The words of Pope Pius II to his architect Bernardo Rossellino on the handover of the cathedral and papal palace of Pienza, cited in Hale (1993, p. 400), showed that he was an unusual client. In renaissance Italy, clients tended to take their patronage of architecture seriously; indeed, Alberti wrote his *Ten Books on Architecture* for the edification of patrons, not for the nascent architects who were slowly emerging from the ranks of the craftsmen at the time (Goldthwaite, 1980: p.97). He was also unusual in that clients do not normally like surprises. Clients expect to pay what they had originally agreed to pay; the building to function as they want it to function; and for it to be ready when they need it. A surprised client is a dissatisfied client; this paper will explore an approach to project management which places the minimization of client surprise at the centre of the project management task.

The paper will start with a brief review of existing approaches to project management, noting that they rarely place the client at the centre of the process, and that they rarely consider the project as a whole. It will then go on to present an alternative approach derived from the service quality management literature which does place the delivery of value to the client at the centre of the process, and treats the project process as a whole. Finally it will validate the framework through a case study of the successful Glaxo project – one of the UK's largest ever building projects. The discussion will be developed by focusing on the problems of managing quality, but it will be suggested in the conclusions that the approach is equally applicable for programme and budget management as well.

Fragmentation and production orientation in project management

The literature on construction project management organization is largely derived from the mainstream organization theory of the 1960s (Winch, 1989), married to the developments in operational research associated with US defence programme of the same era (Morris, 1994) – a combination well exemplified by Cleland and King (1968). Although this is seen in other sectors such as aerospace and energy as a failed paradigm (Horwitch, 1987), it continues to dominate construction project management, which is, in many respects, stuck in a 1960s time-warp (Morris, 1994; p. 217).

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The principal criticisms of the 1960s model are that:

- it is dominated by a concern for tools and techniques rather than the strategic aspects of project management (Morris, 1994).
- that it fails to theorize the implications of managing temporary project organizations formed from unstable coalitions of firms (Winch, 1989).
- it is inherently bureaucratic, dependent upon a mechanistic rationality based on rules and procedures (Navarre, 1993).
- it is maladapted to the much more dynamic and complex environment of contemporary project organizations (Horwitch, 1987).

To these, already devastating, criticisms this paper will add a fifth – our approach to project management is both inherently fragmented, and orientated towards the needs of the producers in the project coalition rather than the client.

Most construction project management texts – an influential example is Barrie and Paulson (1993) – focus upon the management of site operations, implicitly assuming that the design stages, where the key decisions are taken, are unproblematic. Hellard (1993) espouses a total project approach, but in practice focuses on issues of quality assurance and audit, again assuming that the setting of the standards to be assured and audited is unproblematic. More recent work has focused on the design management task (Allinson, 1993; Gray, *et al.*, 1994), but this literature tends towards inverting the problem by not discussing the management of site operations. Perhaps only Pugh (1991) comes close to conceiving of the project process as a whole, although his focus remains on engineering design. Clearly, trenchant analysis requires specialization – there is considerable benefit in focusing upon part of a business process in order to optimize it, but subsystem optimization easily degenerates into system sub-optimization if the part is not examined in the light of a full understanding of the whole. What is required is a total project orientation instead of the present fragmented approach.

A second problem with the existing literature is its concentration on the problems of producers, rather than providing value for the client. Many widely used construction management texts do not even mention the client. Others, such as Allinson, provide extensive discussions of the problems of producers such as architects in which the client appears merely as a backdrop. The structuralist project management literature focusing on choice of procurement route, such as Masterman (1992), does take the client more seriously, analysing the relations between client requirements and the appropriate choice of procurement route. However, there is little evidence that the procurement route of itself makes any difference to client satisfaction. The aphorism that on successful projects the contract stays in the draw is profoundly true – an appropriate procurement route is a necessary not sufficient condition for the minimization of client surprise. What is required is an orientation towards delivering client satisfaction, not allocating liability once the client is dissatisfied.

The gap analysis approach

Construction is a service industry – clients purchase a capacity to produce and not a product. It is, therefore, to the service quality management literature that we turn for help with developing a new approach which meets the two criteria identified in the previous section. One of the most influential developments in the service quality management literature has been the gap analysis approach developed by Parasuraman *et al.* (1985). This focuses on the analysis of the gaps of perception between the service that consumers expected that they were going to get, and their perception of what they actually got. Five principal gaps are identified:

Gap 1 – between consumer expectation and management's perceptions of consumer expectations.
Gap 2 – between management's perception of consumer expectations and management's translation of those perceptions into service quality specifications.
Gap 3 – between service quality specifications and actual service delivery.
Gap 4 – between actual service delivery and external communications to the consumer about the service.
Gap 5 – between actual service delivery and the consumer's perception of the service.

In further empirical work using the SERVQUAL instrument (Zeithaml *et al.*, 1990), the research team have validated the model and developed the model further by adding the concept of the *line of visibility*. This is defined as the level of transparency of the process of service delivery for the consumer.

The gap analysis approach offers both a conceptual framework and a methodology which meets the two criteria defined above. Firstly, it is concerned with the total process of service delivery; secondly, it is focused first and last on consumer satisfaction. Gap 1 zooms to the consumer's entry into the service delivery process, while Gap 5 zooms to the consumer's exit, but the whole process is kept in the picture. There is evidence from research on project success factors that a perceptual approach such as this would be appropriate. In a study of 646 projects, 22% of which were in

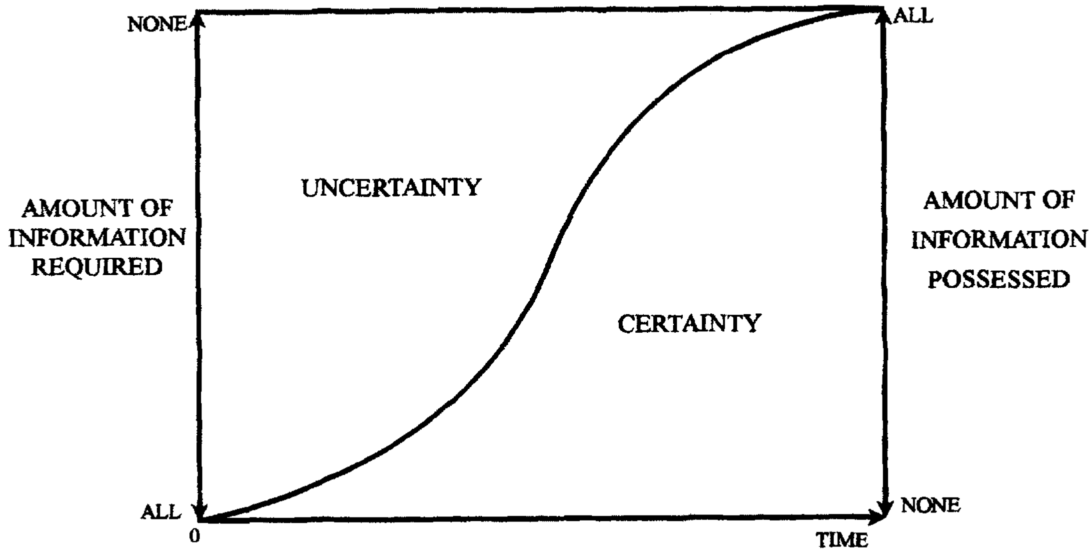

Figure 1 The project process: the information flow

construction, Baker *et al.* (1988) report that perceptions of the project outcome are more important to project success than meeting any particular project objectives. Pinto and Slevin (1988) have argued in a similar vein, emphasizing the importance of including 'client satisfaction' in the measurement of project success factors. More recent work in Britain based on interviews with a random sample of 138 clients found that while there were no direct correlations between client satisfaction and *actual* time and cost outcomes, 'performance *relative* to anticipated duration and cost was the baseline used for appraisal' (their emphasis: Bresnen and Haslam, 1991; p. 337). However, the model as it stands is developed for mass services such as restaurants and doctor's surgeries, not for production on a site-specific, one-off basis as in construction. The sole application of the approach in construction of which we are aware (Touche Ross, 1994) focuses on the architectural practice as a professional service firm, not on the project organizations to which it supplies resources. The adaptation of the gap analysis model to project orientated production will be the topic of the next section.

The nature of construction projects

The distinctive characteristics of constructed products are well established (Nam and Tatum, 1988); the discussion here will focus on the nature of the project process by which they are created. The process of production of any good or service is, essentially, a flow of information; in the case of goods, this flow of information stimulates and controls a flow of materials (Winch, 1994). The construction project consists principally of such an information flow which both specifies the character of the flow of materials on site, and controls that materials flow against the specification. Taking Galbraith's (1978) definition of 'uncertainty', this *project information flow* can be thought of as a process of the continual reduction of uncertainty through time. The one-off nature of the construction project means that it is inherently innovative, and that very little is known at inception about the completed building; at hand-over, information about the building is complete. The nature of this flow is illustrated in Figure 1, which shows how uncertainty is replaced by certainty as the project progresses.

As this information flows through time, it passes through a number of screens (Wheelwright and Clark, 1992), which represent the major decision points at which the flow is narrowed and uncertainty significantly reduced. As the information flow passes through these screens, its character changes. As Bobroff *et al.* (1993) argue, in the upstream phase the issue is to maximize the exploration of options; in the intermediate phase, the problem is to choose clearly and decisively, thereby freezing the project; and in the realization phase, the objective is to mobilize as quickly as possible the project due to the heavy financial investment which takes place during this phase. Wheelwright and Clark also identify three phases of maximum search, definition of options, and development of specific products. Sidwell (1990), focusing more specifically on construction projects, distinguishes between institutionally orientated, professionally orientated and mechanistic phases culminating in the bureaucratic phase of commissioning.

The conceptualization of the construction project process as an information flow which decreases uncertainty through time while specifying and controlling a materials flow on site, has the advantage of balancing the whole and the parts. It places the management of design at the centre of the project management task, while retaining the traditional stress on site operations. By characterizing the different phases of the project life cycle as modulations on the overall information flow which are screened from one another by key decision points, it shows how upstream and downstream activities are mutually dependent, but present different types of management task. The combination of this view of the project as a flow of information with the gap analysis model developed previously will be the subject of the section after next. Before then, however, a brief digression on quality is required.

A digression on quality

The traditional triangle of project objectives (Barnes, 1988) stresses time, cost, and quality. This triangle hampers understanding of the project management task in two ways. Firstly, it is not clear whether the model is addressing the process of setting objectives, or executing against objectives previously set. As will become clear from the following discussion, the project management task includes both the setting of project objectives in interaction with the client, and realizing the project against those objectives in a consummate manner.

Secondly, the term 'quality' in the triangle is ambiguous; an ambiguity embedded in a much wider conceptual confusion. The following is offered as one way of clarifying the issues. Quality can be defined in four ways in construction,[1] and the most appropriate techniques for managing each vary according to the problem at hand. Firstly, there is the quality of *conception* in terms of elegance of form, spatial articulation, contribution to the urban culture and the like. This is best managed through techniques which emphasize the role of peer review such as crits within the architectural design team, and design reviews more widely within the project coalition. The quality of *specification* refers to the technical standards set for the building and the level of finishes required. Fitness for purpose is the keynote here, and techniques such as value management and life-cycle costing are well developed quality management tools for establishing appropriate levels of specification. The quality of *realization* is determined by client review of the process, and those techniques associated with total quality management such as customer-oriented organizational learning are most appropriate for managing this form of quality. Finally, the quality of *conformance* concerns the manner in which the objectives set for conception, specification and realization are met in practice. Here quality assurance and control techniques are most appropriate.

[1] The first three of these were identified in Winch and Schneider (1993).

The gap analysis model for total project quality

A combination of the gap analysis model, and the model of the project as an information process is illustrated in Figure 2. The model distinguishes four problems to be solved for the minimization of the *project performance gap* between what the client thought they were going to get and what they actually got. The smaller the project performance gap, the smaller the level of client surprise and, hence, the greater the level of client satisfaction. In order to minimize the project performance gap, the previous four gaps must be

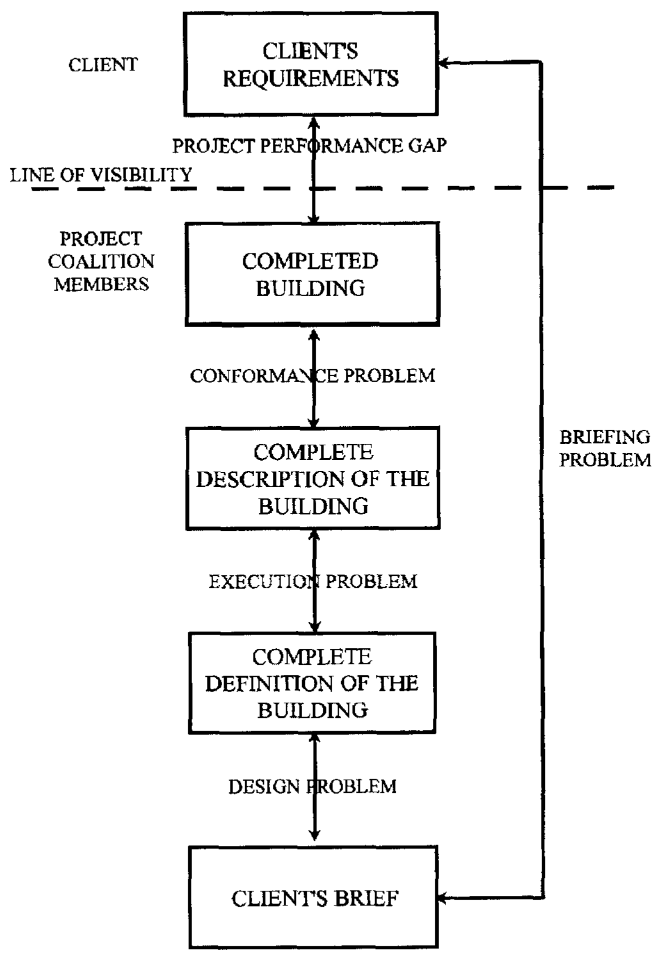

Figure 2 The gap analysis approach.

minimized through the consummate solution of the problem at hand. They will be discussed in turn.

The *briefing problem* is the process of turning the client's desire for a built product into a clear *brief*. On complex projects this stage may take many years as various schemes are developed, evaluated and rejected. While the Channel Tunnel is perhaps an extreme example, it is not unusual for large infrastructure projects to be at this stage for decades. Even relatively small projects, such as the refurbishment of inner London housing stock can be stalled for a long time. The principal issues here are financial and political, as resources are sought and the objections both within and outside the client organization are overcome. Many projects fail at this stage (Horwitch, 1987; Morris, 1994), sometimes because they are bad ideas, but also because the right combination of opportunity, finance, and political will cannot be found.

As Sidwell (1990) points out, information processing at this stage is outward-looking, or divergent. Essentially, the problem here is a special case of strategic decision-making. The case for the project needs to be related back to the client's overall corporate strategy, and the facilities strategy which forms a part thereof (Nutt, 1993). A wide variety of skills are drawn upon including those of architects, planners, and engineers who can envisage the options for the final product; management accountants and cost consultants who can establish preliminary budgets; environmental consultants; and project managers who can champion the cause of the project both within the client organization, and more widely in society if needs be. The outcome of this stage is a decision to build, a definition of project objectives, and a *brief* to which the designers can begin work. Unless this brief is viable in terms of the client's objectives, then the subsequent phases can do little to rescue the situation.

The solution of the *design problem* is, perhaps, one of the most contentious aspects of the project process. The root of the problem is that the built product is simultaneously a private and public good. The solution of the design problem must not only refer to the client's objectives as expressed in the brief, but also the public interest as expressed in issues such as conservation of the urban fabric or rural landscape, or the cultural heritage of the society (Prost, 1992). This dilemma is most obvious when the client is a public agency, but is present to some degree on all construction projects. Put in terms of the four-part definition of quality above – the quality of conception is often in tension with the quality of specification and realization. There is no compelling reason why the judgement of peers and the judgement of clients should be in agreement regarding quality, and these are matters of legitimate debate between the project actors and, often, more widely.

The nature of information processing at this stage has been the matter of some debate (Cross, 1984). The model associated with the design methods school of analysis-synthesis-evaluation has been roundly criticized as formalistic and inaccurate, and a conjecture-analysis (Roozenburg and Cross, 1991) model is now more widely accepted. Thus information flows at this phase are of an iterative (Sidwell, 1990; Winch 1994) character with intensive interactions within and between the various design teams working on the project, the outcome of which is a *complete definition* of the built facility. The principal actors during this phase are the architects and engineers, supported by a variety of specialist engineering consultants as required. Thinking here switches from being divergent to a more convergent mode as information processing focuses in upon the objectives established by the brief.

Despite a clear brief, much can go wrong during this phase. Unless the recursive cycles of conjecture and analysis are effectively managed, it is easy for the actors to favour conceptual quality, supported by a rhetoric of the public good or professional integrity, rather than the quality of specification and realization. The essential management process is one of propose and dispose (Hillier, 1978) in which the design team proposes and senior members of the design practice dispose of the proposition favourably or otherwise. One of the most importance questions for the management of this phase is who outside the design actors in the project coalition are placed in the role of disposing – other candidates include the client, and the principal contractor. The inherently innovative nature of the design process means that it is impossible to specify the outcome of this phase in advance – what can be done is to specify clearly the criteria which the building definition proposal must meet to pass through the decision screen to the next phase. Quality management is mainly orientated to the quality of conception, supported by the quality of specification.

The *execution problem* is that of turning the definition of the building into a *complete description* that allows site construction to take place. In the terminology of the Reading team (Gray *et al.*, 1994), this is the transition from the scheme to the engineering phases of the design. Thus detailed working drawings have to be prepared, engineering calculations made, and components specified. Plans for the next phase in terms of programme and budget are laid, while the documentation required for the procurement of trade contractors is also developed. Here the information flows become more reciprocal in character – the actors are working to a clearly defined problem, but feedback to the actors involved in the earlier phases may also be required to resolve inconsistencies and absorb new information. Research for the Building EDC (1987) shows how failure to manage this problem effectively can generate considerable difficulties in solving the conformance problem on site.

The actors involved here vary very much according to practice within the contracting system. Thus in the French system, the main actor here is the principal contractor, while in the traditional British system the architect and engineers, joined by the quantity surveyor are more important (Winch and Campagnac, 1995). The choice of procurement route will also have a large influence on who leads the project coalition in solving this problem, and, increasingly, trade contractors are being brought in to provide their specialist expertise. In many ways, who is best placed to facilitate the resolution of the execution problem for the client is one of the most contested questions in the contemporary construction industry, with a wide variety of actors staking their claim. Here, quality management is mainly orientated towards quality of specification, but also the quality of conformance.

The final problem to be resolved is that of the *conformance problem* – the outcome of this phase is the completed building. Here the task is to build to the complete description of the building, and to ensure that the result works as a system. Sidwell (1990) characterizes the information flows here as sequential. While this might be the ideal, it is often not achieved. Uncertainty regarding ground conditions can have a significant impact on new build projects here, while on refurbishment projects this uncertainty remains for longer. The greater complexities of information flows on fast track projects also militate against a sequential approach. Elements of reciprocity in information flows are still required. The main actors involved here are the principal and trade contractors, perhaps supervised by others who were involved in the design and execution phases. The main quality management problem here is the quality of conformance – ensuring that what is actually built conforms to the building description.

The difference between the client's perception of the completed building, and what they were expecting to receive upon handover is the *project performance gap*. The key to minimizing the project performance gap is having no surprises. The project process is an inherently uncertain one, and by the time errors of decision due to bounded rationality have become apparent, it is usually too late to do anything about it. Objectives will change in both detail and general through the project process – the key to client satisfaction is twofold. Firstly, that the client understand why changes that it has not initiated have taken place; secondly that the client understands the full implications of the changes that it has initiated. Thus the appropriate location of the *line of visibility*, which defines the transparency of the project process for the client, is a key decision in defining project objectives as part of resolving the briefing problem.

This discussion has aimed at applying the gap analysis model for service quality management to the distinctive context of the management of construction projects in order to develop a model of total project quality which both overcomes the fragmentation inherent in existing models, and also places the client at the centre of the process. It identified four different mutually dependent problems that have to be resolved through time in order to minimize the project performance gap, and hence maximize client satisfaction in terms of the quality of realization. The nature of the information flows, and hence the nature of the management task, varies significantly between the problems – the project management skills most appropriate for facilitating the resolution of the briefing problem are very different from those appropriate for the conformance problem. Similarly, the most appropriate management tools and techniques will also vary. These issues will be revisited in the conclusions, but first it will be helpful to explore the application of this model to a particular project, and we have chosen the Glaxo project – the largest British building project in recent history – to test the robustness of the model.

A case in total project quality: the Glaxo project

The Glaxo project was a major building project requiring an innovative approach; the gap analysis model presented above helps us to learn a number of important lessons from the experience of this successful project.[2] The background details of the project are given in Appendix 1, here the analysis will focus on the application of the gap analysis model to the project process, and indicating the actors involved in resolving each of the quality management 'problems' and the overlapping responsibilities of the project coalition members for that process.[3] First, however, the organization of the project will be briefly presented.

Project coalition structure

The three principal members of the project coalition were The Kling Lindquist Partnership (TKLP), as Master Planner; a consortium of Ove Arup (engineers),

[2] In March 1995, the client officially declared the project a success – completed on time, under budget, and to user satisfaction.

[3] The research reported here was funded by the Euroconception programme of Plan Construction et Architecture, and an Economic and Physical Sciences Research Council doctoral studentship awarded to the last named author.

Sheppard Robson (architects), and Davis Langdon & Everest (cost consultants) as the Principal Architect Engineer (PAE), led by Ove Arup; and a consortium of Laing Management and MK Ferguson as Principal Contractor (PC). The client was Glaxo Group Research Ltd, a subsidiary of Glaxo plc, one of the world's leading pharmaceutical companies. They established a large in-house project management team (GGR), staffed mainly by project managers from the process plant industry. The PAE and PC were both appointed on a cost-reimbursement basis. Trade packages were let on a fixed lump-sum basis with the PC acting as a management contractor. For the pre-site phases, all the PAE and GGR staff were located in the same central London office, where they were joined by engineering staff of the PC and trade contractors and some key component suppliers as appropriate.

There were considerable overlaps in responsibilities between the three principal actors. TKLP were appointed in January 1990 on the strength of their work for Glaxo at Research Triangle Park in the USA, but within four months, a team from the PAE were seconded to the United States to liaise and, in particular, provide input on UK norms and regulations. The PC was appointed in August 1990, and from then on the project was effectively managed by an executive triumvirate of the senior manager from each of GGR, PAE, and PC. PAE chose a matrix organization of design discipline by building for its internal organization, while GGR and PC opted for functional organization. The project presented here is the second one on the site – an earlier project had been abandoned by Glaxo in 1989 and all construction contracts except one determined due to rapid inflation on the Design and Manage contracts.

The basic principle of quality management on the project was that each actor in contract with the client was responsible for all outputs of the phases for which they were responsible. Thus PAE was responsible for the quality of all design information, regardless of who had generated it, while PC was responsible for inspecting and accepting all work carried out by trade contractors. PAE had no site supervisory duties.

The briefing problem

The briefing problem is closing the gap between the client's requirements and the project coalition's perception of the client's requirements. This gap can be reduced by improved communication and complete involvement of the client. In order to solve this problem, the client's previous experiences of similar projects and a clear understanding of their own requirements are vital for the successful development of the client's brief. On the Glaxo project, the briefing problem was handled by TKLP with support from PAE. Glaxo determined the scope of the project by identifying their objectives under two headings.

1) Strategic scientific objectives:
   - Removing technical and statutory restrictions on research by providing superior facilities.
   - Consolidating UK research on one site.

2) Project objectives:
   - Provision of facilities for Glaxo Group Research to meet its commitments under the corporate research strategy.
   - Cost effectiveness.
   - Security and safety of scientific personnel and property.
   - Functional efficiency of the facilities.
   - Completion of the facilities within the agreed schedule.
   - Encouragement of communication and interaction of scientific personnel.
   - Creation of a humanistic and motivating environment.
   - Flexibility of growth.
   - Responsiveness to site and environment.
   - Creation of a strong corporate image.
   - To be the safest construction site in the UK.
   - Accommodation of ongoing construction works.

The above lists of objectives show the objectives of the client. They locate the project objectives within the business objectives of Glaxo Group Research Ltd, and emphasize the importance of the quality of conception and specification within project objectives. The approach to the quality of conception, in particular, developed between the cancelled and successful project. In the review of the failed project, where design responsibility had been delegated to six design and build or design and manage contractors, the inappropriateness of the spatial articulation of the buildings for encouraging the information interaction of the research scientists was identified.[4] TKLP spent a year developing the client's brief, aided by PAE. They used five main sources of data: Glaxo Group Research's own experience with research facilities; TKLP's previous experience on similar projects; interviews with operational and user groups; the experience of PAE with UK conditions; and relevant UK Codes and National Standards. The resolution of this problem resulted in the Control Documents, one for each building, together with a Master Plan layout at 1:750 and

[4] Penn and Hillier (1992) emphasize the importance of the spatial articulation of research laboratories for facilitating innovation.

Building Block Layouts at 1:200.

A typical Control Document contained both qualitative and quantitative data for the individual spaces to be accommodated within the structure. Detailed analysis of information was carried out by each discipline, such as architectural, structural, HVAC, electrical lighting, plumbing and fire protection. Control documents also contained technical information, recommendations of the type of systems to be used, and relevant sketch drawings to explain a system. An initial cost estimate at +/– 35% and a master programme were also prepared. Throughout this phase of the project, detailed review meetings were held with GGR. The Control Documents therefore represent an agreed brief for the project.

The Control Documents can be divided into two sections.

1) Statement of Criteria (SOC)
   The SOC listed criteria for specific buildings as well as standards which were applicable to all buildings on the research campus. The SOC can again be divided into two sections:

   Design Criteria. This section primarily described the engineering objectives and constraints, according to which the proposed facility was to be designed. For example, the architectural criteria include the functional space programme, the building design concept, and the exterior and interior materials to be used. Similarly, the HVAC criteria listed standards of indoor design temperature, humidity, sound and ventilation. In addition to these general criteria, specific details were also provided for the chemistry building. For example, provision of Fume Cupboards in this section of the campus was set as an essential criterion for the safety of the scientists who would be working in this building.

   Space Criteria Tables. At the end of the SOC, detailed tables were provided summarizing specific criteria for the chemistry building. This formed the basis for Room Data Sheets, giving details of the requirements in each room. For example, under the architectural section finishes for the floor, walls and ceilings were listed for separate rooms, ceiling height and door types were also determined and presented in the form of a table.

   The SOC is a document which attempts to define all the relevant data and information that TKLP had collected from all its sources. It systematically listed the relevant information after considering the client's requirements. It also gives a clear picture of what the design teams needed to aim for, in terms of standards and equipment. In short, the SOC is a document which describes in great detail what the client's requirements were, in conjunction with the technical information needed for such a complex and large scale project.

2) Basis of Design (BOD)
   SOC was used as a base for developing the second section of the Control Documents known as the BOD. The design criteria from the SOC document were used to recommend technical systems which were to be used in the building. Therefore, heating loads were calculated in the SOC document whereas heating systems were suggested in the BOD document. In addition to this, drawings were also provided where necessary, for example heating system flow diagrams were included to explain the system in detail. Therefore, the BOD is a much more detailed and explanatory document and identified those specifications which are considered by the client to be vital for the success of the project.

The Control Documents and layouts constitute the principal information input to solving the next problem of the gap analysis model, the design problem.

The design problem

The design problem, in terms of the gaps model, is the process of translating the client's brief into a complete definition of the building. In other words, it is to translate the Control Documents and master plan into a scheme design. The information flow went through a number of iterations during this phase as the building definition became increasingly elaborated. Building layouts moved from 1:200 to 1:100; engineering designs moved from schemes to general arrangements, equipment data sheets were developed, and cost estimates were developed at the +/– 15% level.

The quality management approach to resolving the design problem, and also the execution problem which will be reviewed next, is codified within the PAE's Project Quality Plan (PQP), based on Ove Arup policies. While capturing the spirit of formal quality assurance procedures under BS 5750, it had not been certified due to the heavy documentation that this implies, which is considered inappropriate for the work of Arup. The PQP contains two types of information. Firstly, it contained procedures for the assurance of quality at various stages of the process. Secondly, it defined the arrangements for reviews and audits of the process. A design review was defined in the PQP as

> 'a formal examination of the design to evaluate the design requirements and the capability of the design to meet those requirements and to identify problems and propose solutions.'

The specified design reviews were of two types. Final Design Reviews occurred at specified stages of the project. They were organized by the PAE, and undertaken by the PAE Executive, consisting of the Project Director and five directors from the three member firms of PAE consortium, and GGR staff. TKLP and PC staff also participated as appropriate. These were complemented by Interim Design Reviews which took place as required within the PAE, and which included GGR staff as appropriate. At each review, a Quality Review Record was completed, and the project manager of each of the six design teams committed to implementing the decisions taken. In addition to these design reviews, the architects (Sheppard Robson) carried out internal crits as their contribution to the resolution of the design problem developed.

Provision was also made within the PQP for Design Audits of the quality management process during the resolution of the design and execution problems. A Design Audit was defined in the PQP as:

> 'A separate internal examination to determine whether the design activities and related results comply with the planned arrangements and whether these arrangements are effective and suitable to achieve given objectives.'

While these audits were internal to the PAE, GGR staff were also invited to attend.

Two Final Reviews took place during the design problem resolution. The Concept Review took place when TKLP handed over the Control Documents. This review marked the point where PAE formally took over the responsibility of the project, therefore, a complete understanding of the design solutions recommended by TKLP was vital for the development of a positive attitude between all parties involved. The PAE team value engineered the master plan during the Concept Review and identified a 'few areas where some kind of a change was needed'. In order to continue to have a high level of communication between the two parties, TKLP remained involved during the resolution of the design problem and continued to comment on the development of design as carried out by PAE.

The second Final Review was the Design Adequacy Review, which marked the establishment of the complete building definition. Its aim was to ensure that the client's objectives as defined in the Control Documents were met in the work produced, and that the design packages for the work to be carried out for the execution problem had been clearly determined.

The execution problem

The execution problem starts with the building definition, and develops the information required to provide a complete description of the building so that work can start on site. General arrangement drawings at 1:50, detail drawings, and technical specifications were developed, together with the documentation required for the tendering process. While TKLP ceases to be active, and the PC plays a much greater role, the resolution of this problem remains the responsibility of PAE. Design reviews remain important, but quality assurance procedures begin to have a bigger role to play.

The PQP clearly distinguishes between quality assurance (QA) and quality control (QC). QA was defined as

> 'a programme or plan covering activities necessary to provide quality in the work to meet the project's requirements. Quality assurance involves establishing project-related policies, procedures, standards, guidelines and systems necessary to produce quality.'

QC was defined as

> 'the specific implementation of the quality assurance program of plan and includes checking and reviewing design related activities. Effective quality control reduces the possibility of errors and omissions.'

Two Final Reviews were conducted during this phase. The Final Package Scope Review was undertaken two months after detail design had started on each package. Its objectives were to confirm that the building was dimensionally coordinated across the design disciplines, to check that the scope statement for each package was clearly defined, and to ensure that the interface requirements between packages had been identified. The Pre-Issue Review was undertaken one week before the design release date for each package. The issues here were the formal coordination of the drawings, the checking of drawings and specifications to ensure completeness and accuracy, and the documentation of interface requirements with other packages.

Much greater emphasis in the PQP is placed during the resolution of the execution problem on quality assurance procedures. The more important procedures specified are:

1) Design control and co-ordination.
   The purpose of this section is to describe procedures for the control and coordination of the design related activities in order to ensure conformance to the Control Documents. It specified the manner in which design inputs and outputs were documented, monitored and reviewed. For instance, the use of QAQC (Quality Assurance and Quality Control) forms which were signed off by the relevant design discipline leader and member of the project executive, approving the work of the design teams was defined.

2) Design Documentation Control.
This section included description of practices and procedures for the control of design documents including production, identification, distribution and filing of the relevant information. It included procedures for:

- Document approval and issue:
The drawing issue procedure was a three stage one of produce and check; correct and sign; and issue. All documentation issue was done through the Project Control Group which reported direct to the PAEs Project Executive.
- Document change and modification:
All design changes were to be requested in writing, and their review and issue to relevant personnel to be documented.
- Document control scope:
This specified communication media to be used such as verbal computer disks, microfilms and so on. It also listed the points of control such as circulation control, issue and authorization of originals, recording of document status, and withdrawal of superseded documents.
- Project specific requirements:
This section included procedures to be followed to provide information regarding published reference data such as standard specifications and national codes held in the PAE library.

In addition to these quality management procedures, GGR established an Engineering Quality Control (EQC) department consisting of 12 engineers experienced in the design of pharmaceutical process plant which was responsible for reviewing the output from the PAE in this specialist area. The areas for improvement fell into two categories – those which could be incorporated into the design without delay and cost, and those that required a formal change order. The vast majority of improvements fell into the former category. All those proposed changes that had a cost implication were formally costed by PAE, and the final figure arrived at was a saving of between £4m and £5m, achieved without compromizing the functionality of design.

The conformance problem

The management of the conformance problem on the Glaxo project was a sophisticated application of standard approaches to quality assurance and control. Figure 3 illustrates the overall structure of the QA procedures for the PC's areas of responsibility in accordance with BS 5750 Part 2. The Project Quality Plan provided for document control, trade contractor pro-

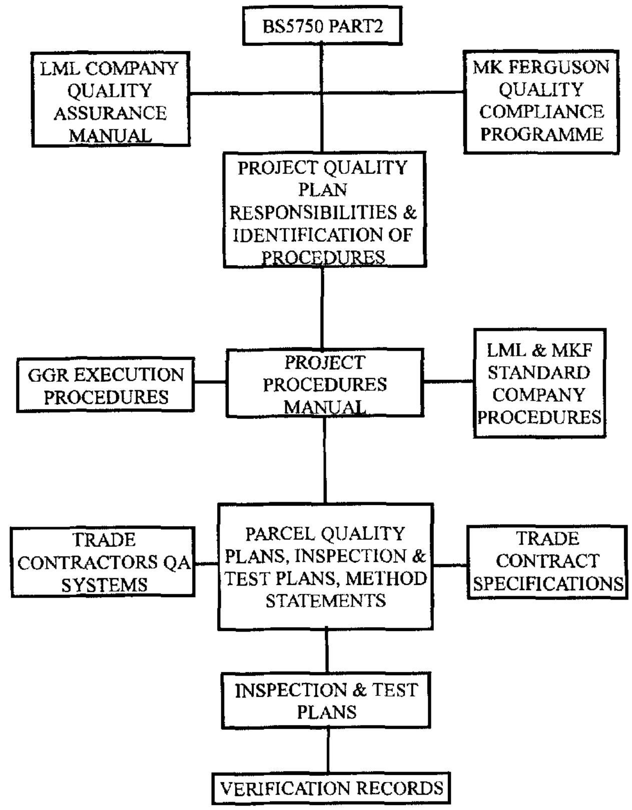

Figure 3 Quality assurance systems – The PC

curement, parcel grading, and the role of GGR. On a management contract, the quality assurance capabilities of the trade contractors are central to the successful resolution of the conformance problem. Pre-tender qualification was based upon track record, financial strength, quality management capability, and commitment to the project. GGR vetted the tender list prepared by PC, and sought references from trade contractors' previous clients. Quality Statements were sought at tender stage, which became comprehensive Quality Plans for the successful trade contractors. These also included Inspection and Test Plans and the arrangements for the in-process inspection of the production of prefabricated elements, and on-site inspection. The PC's PQP was subject to annual management review as well as a programme of audit for both their own activities, and those of the trade contractors.

Work packages were graded in terms of their criticality for project performance. Thus the M&E installations and the production of the pre-cast concrete elements were given a higher grade than the general painting. This particularly affected the Inspection and Test Plans. At the highest grade, a comprehensive quality control regime was in place. Where third party testing was specified, the PC and GGR were contractually invited to be present at the tests. Another clause in the trade contracts gave GGR or its representatives the right of access to the works at all times for the purposes of inspection and verification. These control procedures were most important during commissioning, and the commissioning reports then formed part of the QA documentation.

Discussion

Overall, the project can be rated as a considerable success. A combination of effectively motivated actors, the co-location of all the design teams, sound systems for the management of programme and budget, and the lessons learnt from the earlier unsuccessful project provided a solid foundation for the management of quality. However, not all went to plan. One of the major problems turned around what was meant contractually by complete design, or in the terms of the gap analysis model, the complete description of the building. In order to tender on a lump sum basis, the trade contractors required adequate information. The first problem was that differences between British and American practice in what was meant by complete design showed themselves. Secondly, incompatibilities between the different CAD systems used by the engineers and the architects meant that issued drawings were not always fully coordinated.[5] Thirdly, the use of detailed performance specifications as complete design of the M&E services, leaving the trade contractors to select the actual equipment, meant that there was considerable uncertainty regarding information such as plant sizes. This meant that design with trade packages affected other packages.

The solution to these problems was two-fold. Firstly, up to 70 trade contractor and component supplier engineering staff co-located with the PAE to resolve the problems. This implied a shift away from pure lump-sum contracting to nomination of suppliers on the basis of a combined price and technical offer for the affected packages. Component suppliers were selected, and there then followed a period of design development until the trade package could be tendered and a final price fixed. Secondly, the task of recoordinating the trade contractors' installation drawings arose. GGR chose to award this to PAE, who employed design coordinators separate from their integrated design team to execute it. Another implication of these changes was that the number of site-wide packages grew from 5 to 96, and some 5 months was shaved off the contract period.

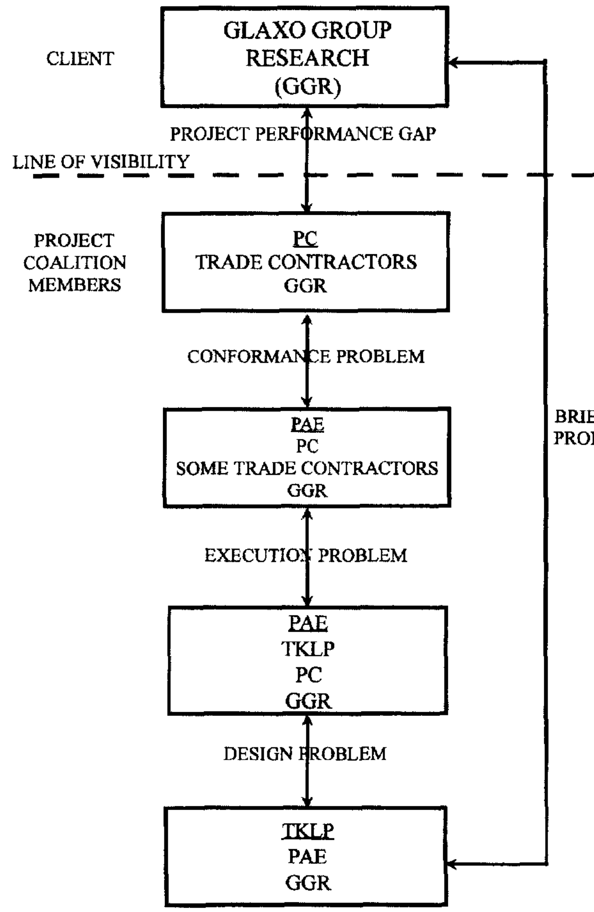

Figure 4 The Glaxo project actors

Figure 4 shows the involvement of the different project coalition members in solving the four problems. As might be expected, the 'wheel of dominance' (Murdoch and Hughes, 1992), shifts as problems are resolved and the information flows on. TKLP were the prime movers in solving the briefing problem, with help from PAE. They in turn were dominant in the design and execution problems, with the other principal actor changing from TKLP to PC as the project moved on. For the conformance phase, PC were dominant, coordinating and controlling the contributions of the trade contractors. However, there is also a sense in which the trade contractors are the most important actors in the coalition. After all it is they who deliver the built facility – the principal goal of all the other actors is to ensure they can do their job properly, and thereby minimize the project performance gap.[6]

[5] GGR had originally specified that a single CAD system should be used, but were assured by the members of the PAE consortium that this was not possible, and that the two different systems that they already possessed were sufficiently compatible.

[6] This is the principle behind Quality Function Development in which downstream producers are the 'customers' of upstream producers. Dale (1994) provides an introduction, and Shiino and Nishiharia (1990) provide an application to construction.

What is also notable is the continual participation of the client in resolving all four problems. As an experienced client, Glaxo Group Research Ltd were prepared to invest in their own in-house capability to ensure that the project went smoothly. This must be considered to be one of the more important contributors to the success of the project. Their deep knowledge of the project process and why the problems had been resolved in the way that they were meant that when changes were required, discussion took place in a trusting atmosphere. The cost-reimbursable nature of the remuneration of the PAE and PC, together with the open-book accounting which this implied meant that they were fully covered for the extra efforts that they put in making these changes.

As a result of the effective management of the total project, coupled with advantageous use of the construction cycle, the client procured their new facility for some £250m less than the overall figure projected in 1989. For this they paid a significant time penalty due to starting over again, but used the time well to reappraise their needs and to provide a much more coherently and appropriately designed facility. Where the original project had been a series of design and manage contracts under the supervision of a master planner and a site-wide construction manager, the approach adopted here emphasized the facility as a whole and the quality of working life within it.

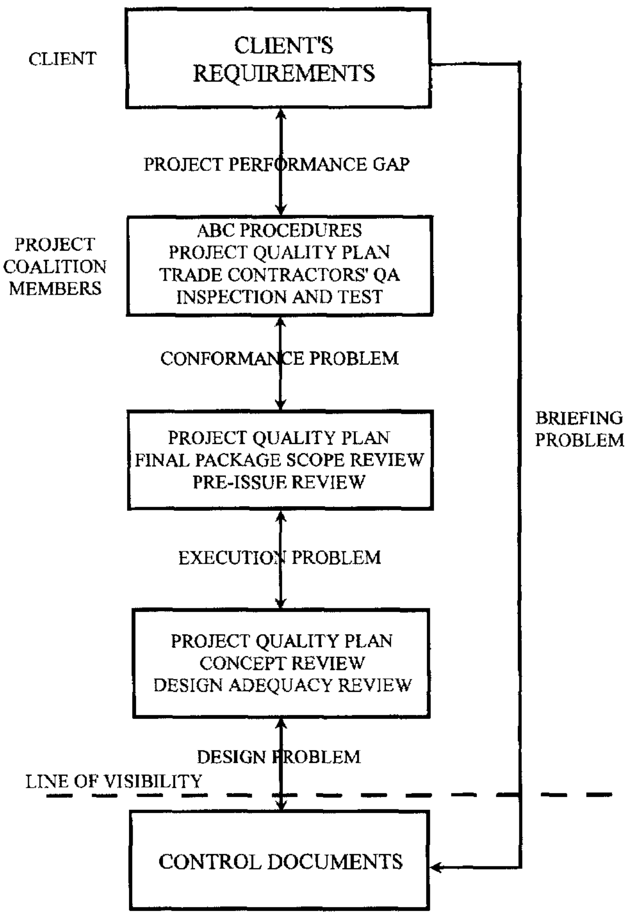

Figure 5 The Glaxo project management problem

A gap analysis of the Glaxo project

The generic model presented in Figure 2 is applied to the Glaxo project in Figure 5. The two main points that can be taken from this are the way in which the appropriate quality management tools vary as the nature of the project information flow changes. In resolution of the briefing problem, quality management depended upon the professional skills of the actors, while the output of this phase, the Control Documents, set the basic quality standards for the project in terms of conception, specification, and realization. For the design problem, the design review became the most important tool allowing the review of progress to date by all the actors, and the checking back of the design against the Control Documents. As the project progressed, and the packages moved into the execution problem, quality assurance and control procedures became more important, although design reviews still retained their critical screening role. For the conformance problem, quality assurance and control really came into their own.

Secondly, the client's line of visibility into the project was very deep. The GGR staff, which numbered around 100 people during the construction phases, took an active role in all the design reviews, and major site inspections. When elements of the strategy needed to be changed, it was clear to GGR why this was so, and no problems of adversality arose within the project coalition. Their role was particularly proactive during the resolution of the execution problem where the EQC department provided a highly effective way of cutting unnecessary cost. Beyond this, value engineering procedures did not form a major quality management tool.

More generally, the case has shown that the gap analysis model presented earlier does provide one approach to total project quality management. It meets the two criteria specified above. It treats the project process, theorized as an information flow continually reducing uncertainty through time, as a whole, and, through the identification of the four gaps, allows the deeper analysis of the different phases of the project life cycle. Secondly, it places the client at the centre of the project process through the concepts of the project performance gap and the line of visibility.

Conclusions

This paper started by identifying the weaknesses of our existing approaches to the management of construction projects, and the limitations of relying only on hard, quantitative, measures of project performance for the assessment of project success in a service industry like construction. Although the recognition of such weaknesses and limitations is now becoming commonplace, little progress has been made on articulating an alternative. Business process reengineering (BPR) is being widely advocated, but it remains far from clear how such a technique, developed in the mass service industries and for back office processing in the mass production industries can be applied to project orientated industries such as construction. What BPR and the gap analysis approach to projects identified here have in common is firstly, the definition of the business or project process as an information flow, and secondly, a concern for the total process of delivery of value to the customer.

The gap analysis approach to the management of total project quality presented here emphasizes the importance of the process of creating the built facility, rather than a focus on the built facility as such. As Walton concluded from his case studies of a number of commercial building projects in the US, 'regardless of building type or talents involved, companies manage the decision-making process rather than emphasize final results' (1988: p.180). From this perspective, the central task of project management is to define the criteria by which the project passes through the successive screens defined by the design reviews. As well as quality criteria, these will include programme and budget 'collars' which become progressively tighter as the project progresses.

It follows that design reviews must be considered one of the principal quality management tools on construction projects. Pugh (1991) and Gray *et al.* (1994) have also noted the importance of design revues for managing the design process. QA and QC can only ensure conformance to quality standards; it is the successive design reviews that set quality standards for conception and specification. Consummate realization of a specification 'right first time' will do nothing to reduce the project performance gap if the specification is not fit for its purpose. Critical issues here include which project actors are to participate at which design reviews, and the timing of the different reviews. Holding a review too early means it will fail to act as an effective screen, while holding them too late means that abortive work may result. Holding a review with all the actors can lead to unwieldy meetings or compromize tendering procedures; leaving actors out risks failing to thoroughly review all the options. Some of the more thoughtful commentators upon quality in construction (Powell and Brandon, 1984; Seymour and Low, 1990) have suggested that quality in construction is achieved through a negotiated order; on the evidence of the Glaxo project, one could add that design reviews are the forum for this negotiation.

The level of visibility into the project process by the client is one of the earliest project management decisions that needs to be taken. Not many clients, even experienced ones, will have either the desire or the capability to push this line as deeply into the process as GGR did. In this sense, Glaxo Group Research Ltd may be as idiosyncratic as Pope Pius II at the opposite end of the line of visibility spectrum, but both were satisfied clients. However, a clear lesson from the project is that a pro-active internal client project management function greatly contributed to the successful minimization of the project performance gap – because GGR participated at all significant reviews, there was no way it could be surprised. This raises the question of whether such project management functions are best organized internally by the client, or procured externally from project management companies. The Glaxo project indicates the advantages of developing an internal project management function, and a recent survey of eight of the leading UK property developers indicates a shift towards establishing in-house capabilities who can then deal directly with the designers and contractor (Al-Whabi Jamali, 1994). Interestingly, Bresnen and Haslam (1991) found that project performance against hard criteria (i.e. time/cost/quality) was better when the client had an in-house architectural team.

The project management of construction projects is presently undergoing a profound change. The increasing realization that all the critical decisions regarding the project duration, how much it is going to cost the client and the standards of quality to be attained are taken long before the project ever reaches the site has led to a quest for new approaches to project management. The gap analysis approach presented here offers a total approach to the management of the project compatible with the basic tenets of BPR. Although developed and tested in the context of the management of quality, there is no reason why the same approach cannot be used to develop the management of programme and budget. However, such a development must await further research.

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Appendix 1

The Glaxo project, our shorthand for the construction of a new European research and development facility on a 30ha site near Stevenage for Glaxo plc., one of the world's leading pharmaceutical companies, can be divided into two distinct projects. The first project was procured under a construction management form with AMEC as construction managers, Gleeds as Principal Quantity Surveyors, and YRM as master planners managing a set of six design and manage, or design and build, contracts. This was abandoned in 1989, as cost pressures pushed the estimated outturn construction cost from £500m to £800m. Nearly all the contracts were suspended and eventually determined, and in early 1990, the project was completely retendered with the exception of the Chemistry Pilot Plant which had already started on site.

The second project started with a value engineering exercise in late 1989, and a very different design philosophy and procurement approach was adopted. The facility was handed over in March 1995 for a construction cost of approximately £550m, and a total project cost, including professional fees and client's management costs of £700m. The facility provides some 130 000m^2 of laboratory facilities and administrative accommodation in nine buildings for 1500 scientists and 500 support staff. Emphasis was placed upon external landscaping and the provision of large, airy circulation spaces. The design incorporates naturally lit covered walkways and nodes for informal interaction. The M&E services accounted for around 60% of the total project costs.

The principal members of the project coalition were the Master Planner, Principal Architect Engineer, Principal Contractor – the latter two each being a consortium. The PAE project organization was divided into six teams; five covering particular buildings while a sixth formed a central design team to facilitate standardization across the site. These teams were matrixed with discipline-based groups for architecture, engineering, estimating and drawing production. This matrix was supported centrally by a Project Control Group. The Principal Contractor was functionally organized with commercial, control, construction and engineering functions supported by safety, industrial relations, and quality assurance services. The Principal Contractor established a separate commissioning team, supported by Glaxo-appointed commissioning consultants.

The three principal project coalition members were appointed on a fee basis with actual costs plus an agreed mark-up being reimbursed. As a result, sophisticated cost reporting systems were developed to ensure transparency of costs for the client. The PC acted as a management contractor, letting fixed price lump sum contracts for the trade packages. Safety was a particular concern, and on this dimension, too, the performance of the project was outstanding. Further data on the project can be found in Edkins (1993); Usmani and Winch (1993); and Tsui Man-yuen (1995).

The project won the 1995 British Construction Industry Awards Supreme Award, as well as the first prize in the building category.