EARLY INCORPORATION OF SPECIALIST M&E DESIGN CAPABILITY

Christine Pasquire, Loughborough University of Technology

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Summary

The M&E installation is systems oriented and therefore places considerable design demand upon the installer. A well planned design will involve the M&E specialist at an early stage to overcome the problems relating to co-ordination and integration of the M&E systems with each other and with the building structure and fabric. This paper highlights some of the problems experienced when the M&E design is undertaken late and/or the implications of its incorporation are not appreciated by the design leader. The paper follows this discussion with examples of some practices that successful overcome and suggests the consideration of some strategic factors within project procurement would simplify and rationalise the design. The ultimate aim of changing the procurement approach is to make substantial cost savings.

Introduction

This paper looks at the existing methods of incorporating specialist mechanical and electrical (M&E) design capability into project procurement illustrating how the Clients needs are not being served by the industry. The paper is aimed entirely at the management of projects where the M&E works are a significant consideration e.g. intelligent buildings, laboratory facilities, computer and communications centre etc. It questions the long term benefit of an economy based on market forces and competition and shows how privatisation policies may ultimately reduce the quality of the construction industry output.

The paper is based on research undertaken at Loughborough University, England which comprised a questionnaire survey of some 200 sub-contracting organisations followed up by in depth interviews with participants with M&E expertise. It examines the roles of the parties to specialist design highlighting the effects of the timing of the incorporation of M&E design into the overall scheme design procedure. Before continuing with the study, it is useful to consider why M&E specialist design is different from other specialist items within a building and of which there are many. The specialist can be divided into two types:

- **product oriented** (e.g. curtain walling) who respond to a performance specification with a product in which the design is incorporated; or
- **systems oriented** (e.g. M&E) who either carry out a design from inception in response to a performance brief, or who develop a basic design from a consultant into working detail (Davis 1994).

Given therefore that M&E works are systems oriented they are also therefore design oriented. It is the incorporation of this design expertise that is discussed in this paper.

A Review of The Current UK Industry

The UK construction industry has undergone far reaching changes in recent years revolving round a change in Client base from public sector employers to commercial clients. The emphasis on the name here is deliberate as it highlights a change in attitude among those that pay for construction works. The public sector, whilst being cost conscious, was also concerned with being equitable and ensuring that all parties to the works were fairly represented. As an employer, it understood that the good health of the industry at large was also good for them.
To a large extent the commercial sector takes the view that "we pay therefore you will do things how we want them" often without considering the broader picture. This results in standard contracts being changed into unrecognisable documentation, a price ridden market and an industry feeling defensive and threatened trying to justify their roles in order to survive. Examples of contracts where collateral warranties were not deemed secure enough and clients (or their representatives) were actually requiring power of attorney over the sub-contractor companies were cited by one M&E contractor interviewed. The consequences of such conditions being written into contracts are very serious indeed.

The traditional Bills of Quantities procurement system no longer reflects the way the industry operates. Nothing illustrates this more strongly than the disappearance of the traditional main contractor who had a large in-house resource base of labour and plant. In reality, main contractors are management contractors sub-letting almost all the construction works to domestic subcontractors on documentation that does not recognise this to be the case. The main differences between management and traditional contracting include the contractual distribution of risk and to a lesser extent, the method of price determination.

The position of the M&E specialist contractor has been eroded by this change in attitude marked particularly by the effects of "dutch auctioning" and the diminishing use of nomination procedures. One result of this is the later and later involvement of the M&E specialist contractor as prices are beaten down. Groom thought that more than ninety nine percent of traditional contracts were awarded on price alone. That the current UK construction industry is still beleaguered with poor performance, waste and litigation indicates that there is a fundamental flaw in the belief that a competitive market alone creates an efficient industry, although it may be effective for the client in the short term.

There is no flaw in the concept of providing a service for a client and no-one would argue against he who pays the piper calling the tune. What is needed is however, is a collective effort to change the construction industry from product oriented to service oriented combined with an new approach to procurement with clearly defined roles and responsibilities.

Current M&E Design Procurement

The design of the M&E works currently incorporates three distinct parties, the M&E consulting engineer, the suppliers & manufacturers and the M&E specialist installers (contractors). Under an ideal design procedure such as that outlined by Gray et al (1994) the consultant M&E engineer would commence the design contribution during the concept and outline scheme design stages with the specialist contractor during detailed design. This is not only not reflected in practice, but the consultants are also constrained to a large extent in their design input by the rapid advances in technology and onset of fee competition. Generally speaking the consultants only produce an outline equipment specification which seeks to incorporate selected plant suppliers and/or manufacturers. In return for this specification or pre-selection and novation, the suppliers and manufacturers provide an element of design detailing. The result of this is that the documentation received by the M&E contractor comprises a performance specification containing separately designed packages which suit the individual specified plant and equipment.

Such are the technological advances in the M&E field that consultants can only have a generalised knowledge of the huge variety of systems available e.g. lifts, fire alarms, sprinklers, IT & communications, environmental & energy control systems etc. etc. Each of these areas have specialist manufactures and installers who have far greater expertise in their individual field than a consulting engineer ever can. In addition these manufacturers and installers are constantly looking towards the development of the next generation of plant and equipment. Watts speculates that the majority of research and development work in the M&E field is undertaken by the specialist contractors and many are also developing prefabrication facilities to maintain competitive advantage.

The structural engineer designs service cores and ducts and indeed the building structure, based on a minimum amount of M&E design detail. This gives rise to inefficient design as, faced with insufficient information, the structural engineer will probably overdesign. The main contract is consequently tendered without the impact of the M&E works on the structure and the construction work being fully considered. The M&E design is not complete until cable/pipe/duct sizes, routes and fixings etc. are fully worked out as these have an impact not only on the building structure but also on the ultimate performance of the system being installed. This level of design detail is always left to the M&E contractor.
When the M&E contractor is finally brought into the project, usually well into the construction phase, they are immediately faced with three major problems. Firstly, the specified equipment manufacturers want to recoup the cost of their design input and so they raise their prices (or cut their discounts) knowing they are the only specified manufacturers/suppliers. The effect of this monopoly factor is significant, Davis (1994) cites an example of a cost equivalent to 9% of the contract total. The M&E contractor is faced with paying the higher price and consequently losing the project or taking the risk that the consultant will accept an equivalent item of equipment and pricing more competitively. This immediately illustrates how the contractor winning a tender on this basis (encouraged to do so by the procurement methods employed) who can’t then get approval for the alternative item will be looking to make up the money through other means. The worst case scenario is that they get into financial difficulty and fail to complete the work.

An other and equally serious consequence of this approach to design specification is that the individual and separately manufactured items of equipment with their uniquely designed supply and support systems may not interface. For example the pumps may not talk to the boiler or the thermal control system may require six electrical connections to the heating plant which only has the facility for four cable connections for the thermal control system - what happens to the other two cables?

The M&E contractor has to produce the detailed design and this process usually highlights a whole variety of problems associated with the following :-

- **buildability** - the ease with which the services are installed. If designed after the building fabric, buildability will be reduced and substantial variations may be required to either or both the services and the building fabric.
- **interfacing** - interfaces give rise to potential problems. They occur between equipment, from equipment to system (e.g. to cable/pipework), from system to system (e.g. fire alarm to security), from system to structure (e.g. service cores not rationalised) or from equipment to structure (e.g. plant room too small for access/servicing etc.)
- **performance** - size, number, lengths, position of cables/pipes required will affect performance of plant. Space occupied by services affects performance of systems.
- **co-ordination** - of both the spatial relationship of the systems to each other and various trade contractors working on the project. Although this latter is more of a management problem than a design their are some design implications especially with items such as suspended ceilings e.g. does a pipe/duct run where a ceiling grid hanger needs to be fixed.
- **late appointment** - it was claimed that the M&E contractor may be appointed as late as 6 weeks before they needed to start on site.

**Causes of Late Incorporation of M&E Design**

The interview highlighted several factors leading to the problems currently experienced by the industry. The most important factors were felt to be the economic climate combined with Government privatisation policy. This has given rise to an industry dominated by price rather than value and by initial price rather than actual price e.g. the lowest tender regardless of what the final account might be. A substantial study of the financial effect or "real cost" of such attitudes is much needed to endorse the many voices in the industry now calling for change.

Allied to the change in economic circumstances, the rise of the management contracting system has been cited as a further underlying cause of difficulty. It is claimed by some specialist sub-contractors that the management contractor has lost the ability to manage construction works due to the remoteness of the management team from the work. The loss of in-house or direct labour from traditional contracting has had the same effect. Traditionally the builder was trade oriented with time served operatives and understood the problems of co-ordination. The first round of managers came from the tools and so were quite successful, subsequent managers came with management theory and no practical experience. Therefore the management and traditional contractor are alleged to have lost the expertise at site level. The fragmentation of the work into small construction packages means more problems with co-ordination are actually arising than previously. One of the major concerns of M&E contractors is that the continuation of this fragmentation into services e.g. letting the different systems as separate packages, will diminish their management expertise and ultimately affect the
quality of the product to the client. They claim to have "added value skills" because they retain large in-house labour forces with the ability to manage. This, they feel gives them opportunities to give full consideration to the time, cost, quality conundrum of fulfilling client need.

The poor use of procurement systems generally has given rise to an unhealthy set of circumstances where contractual risk is being passed on through the industry. The design and build (D&B) method suffers greatly from this process. The Client appoints a consultant design team who develop a tight brief and then pass this over to the contractor who is left with little scope to develop the design but is expected to carry the risk of "fitness for purpose" even where it is the consultant designer who defines the performance criteria and even specifies the piece of equipment. An example of the extent to which some consultants go to ensure they pass risk on was provided by Murray. He received a D&B tender comprising nine volumes of specification of workmanship and materials and detailed drawings to Stage D of RIBA Plan of Work including services drawings in detail to a scale of 1:50. All dimensions including those of all pipes and ducts etc. had subsequently been removed from these drawings to ensure the contractor took the risk for sizing.

The M&E contractor (who is responsible for the design and fulfilling client requirement) is often denied access to the client by the consultant who hides behind the letter of the contract documents rather than considering client requirement and sensitivity. An example of such an incident was cited by Murray. The specification for a D&B laboratory project required fan coil coolers and a noise level of NR 40. The lab had a heat gain of 100KW. As a mechanical engineer, Murray knew it was not possible to satisfy all three criteria but was prevented from discussing the sensitivity of the client to each of the three factors and thus resolve the problem, by a consultant whose response was "you're the contractor - it's your problem". Was this consultant really representing the best interests of the client?

The most extreme example of denying the contractor control over the design occurs when the clients design team itself is novated to the contractor who has little control over them but is expected to take all the responsibility and risk. The main advantage of a Design and Build contract is after all single point responsibility!

Leading on from this are clients who, after tendering, accept a non-compliant scheme. This occurs even when the tender documents expressly state non-compliant schemes will not be considered. The tendering contractor has to choose between preparing a single, compliant scheme (at his own cost) or possibly increase the chance of being successful by preparing a non-compliant scheme as well (also at his own cost).

Murray expresses concern over the fact that D&B tenders are prepared by contractors at risk (at their own cost), adding a substantial non-productive overhead to an industry already slashing margins to less than 5%. An example he used showed the cost to one contractor for preparing a £36M D&B bid was £500K. This can be doubled by the input of specialist installers and suppliers to an industry cost of £1M. If their are three tenderers the cost could be £3M or nearly 10% of the project value. Please note that this does not take into account of the often fairly onerous pre-tender qualification procedures required to become one of the final three tenderers. It is easily possible for the tender costs alone to be higher than the margin on a successful bid. Estimating is the single largest overhead in construction generally. It even more of a burden in the M&E sector where design costs have to be borne by both the manufacturer/suppliers and the installers. The parties should be fairly and openly remunerated for their input into the scheme design thus avoiding the need for clawing back this expense at every opportunity.

There is a substantial feeling of frustration within the M&E contracting industry that clients are not receiving the best from the construction industry because they are generally being badly advised by their consultants. However, many companies are taking steps to resolve this in some quite innovative ways. These methods described here.

**Joint Venturing**

This occurs when a construction contractor and M&E contractor take equal responsibility for the management and contractual liabilities of a project. They effectively become a new entity under its own banner with clearly defined roles within the new organisation.
The application of a joint venture (JV) arrangement lies primarily within the D&B sector of the market as the main advantage of this system is the integrated design and management of the construction and building services. However, this type of JV is lead by the contractor rather than the client as there has to be a very strong working relationship between the two (or more) companies involved. It is possible though, that the client may point prospective tenderers in this direction by requiring an integrated approach to the project design.

The Sheffield Light Railway project, currently under construction, is a successful example of a JV of this nature. This is a joint venture between Balfour Beatty Civil Engineering and Balfour Beatty Power Construction. The civil engineering works range from viaducts to a cut & cover tunnel and include the infrastructure, BB Power Construction are installing the overhead power lines for the trams along with the control mechanisms. A third but small partner to the venture is Balfour Beatty Rail Engineering who are laying the tracks. The services for the project take the form of the signalling and traffic control systems are subcontracted to Siemens Plessey. As previously mentioned, the JV team identified the co-ordination of the services at the road/rail junctions as an area of potential problem. An examination of the construction required at these junctions provides a simple example of the complexity of co-ordination and integration between structure and services demanded.

Where the rails crossed a road, the track is constructed on a designed concrete base. The tram has priority and a system is installed to “recognise” the approach and departure of the tram and change the traffic lights accordingly. In addition, the driver of the tram needs to be informed that the traffic lights have change by a visual signal on the track. Therefore there are three systems, each of which needs to “talk” to the other through a network of ducts in the concrete. On the simplest junction, there are two sets of tracks (up and down) crossing one road with two way traffic. On the most complicated there is a branch in the track and a fourway road junction. To complete the picture, at least one statutory service runs diagonally across most of the junctions. Visualising all this on plan provides an excellent and easily grasped example of the problem of co-ordination between services and structure. Apply the same principles in three dimension (with the vertical aspect of buildings) and one can begin to see why co-ordination of services and building structure is such an onerous task.

M&E Contractor as Main Contractor

As the percentage value or importance (sensitivity) of the services increases, so do the problems of design co-ordinations and integration. Many clients place such emphasis on the building services that they will commission the services contractor first and sometimes as the main contractor but more usually on a design & build basis.

Example of a successful project of this type was cited by Bob Robertson of Taymech whose client (a merchant bank) required a remote computer centre with rigorous services to maintain continuous computer operation. These services included not only the normal heating, ventilating and air-conditioning (HVAC) normally associated with computer centres but also standby generators and guaranteed uninterrupted power supply, data cabling and communications rooms. Their brief was not only to carry out the construction work but also to find a suitable existing building for the purpose. The contract was negotiated with a single tenderer. The client was knowledgeable about construction and maintained a “hands on” approach to the project which was completed on time with the final account settled within four weeks of completion and no claims. A good working relationship was struck between client and contractor and more work has followed the original contract.

The Use of Information Technology

The availability of advanced 3D modelling systems release the potential of computers to aid the integration and co-ordination of design. According to Whitehead, this can be enhanced by an innovative form of joint venturing in which the M&E contractor enters into partnership with a firm of architectural consultants to produce schemes which can then be taken into the market place and sold. This situation changes the face of property development as computer models can be marketed instead of empty buildings, removing the risk of buildings remaining unsold/unoccupied after completion. The models are 3D with walk through facilities and the quality of the graphics are so high that only the most experience IT user can tell them from photographs.
The modelling system integrates with a comprehensive cost data base so that detailed resource breakdowns can enable effective costing, planning and production.

One major advantage of this to the prospective client is that fittings, finishes and other aesthetics can be changed on the "drawing board" without the expense of the refits that inevitably take place when tenants/occupiers move in.

The computer model will remain with the client and form the basis of a building/facilities management system.

To maximise the potential of this development, Whitehead suggests a builder may be included in the partnership for projects where buildability may be an issue.

**Project and Construction Management**

Irrespective of the differences between these roles, all the opinion sampled agreed that a professional project leader can question design changes and prevent designers from overstepping (or under-stepping) their responsibility in interpreting the clients requirement.

Indeed both roles actively encourage all that is good about procurement by clearly identifying the roles of the consultants and contractors, properly planning the project and bringing the specialists in early to allow the incorporation of their design expertise.

The Construction Management Forum (1991) stated that "the underlying aim of the management method of procurement should be to give equal status to the designer and construction manager and to create a partnership with the client, together with optimal involvement of the specialist contractor."

A management method will allow the consultant engineer and specialist contractor to work together to provide value from simplification, rationalisation and innovation drawing from the example set in the USA where clients expect consultants to utilise the skills of the specialist.

The BAA/Lynton/Bovis study went a long way towards confirming this, highlighting areas where up to 41% could be saved on services. Although it was recognised that further study was needed, there is no doubt that substantial saving are achievable by eliminating over-design, minimising bespoke plant and equipment, and working together to simplify and rationalise engineering solutions generally (Davis 1994).

**Benefits of bringing M&E contractor in early**

If the M&E specialist is brought into the design of the project at concept or feasibility stage, their influence on not only the building engineering services design but also the actual building design can be significant.

Watts claims that there is a great temptation to put pencil to drawing board too early without fully considering the implications of building use and occupation. For example in an outline brief requiring an office building for 700 people, time should be spent considering what those people are doing. It is possible to design an internal environment that can improve productivity by say 10% resulting in fewer employees, a smaller building and significant cost savings.

This example illustrates a level of commercial awareness often lacking in consultants who, consequently are not providing as full a service to their clients as they might be.

In addition to the above design consideration, early incorporation of M&E specialist design expertise will lead to cost and time savings. This is an obvious consequence of smoothing out the co-ordination and integration problems identified earlier although no authoritative research has been undertaken to show this. A further consequence is likely to be improved working relationships between the various parties involved combined with a desire to find solutions rather than problems. This reduces confrontational posturing and allows all parties to fully participate in what should be everyone's ultimate aim - fulfilling client requirement.
Strategic elements for the successful procurement of specialist design

For the specialist design to be successfully and adequately incorporated into the building there are certain fundamental considerations that should be investigated in full. These are discussed in the following pages.

- The procurement of the design

The procurement of the design service itself may not always be as straightforward as imagined. The choice of a design and build route may be suitable for the construction work but does not fully address the M&E design. Likewise the use of a traditional design team may also not optimise client requirement in terms of building services.

The only way to adequately address this is to evaluate the significance of the building engineering services from the beginning. The significance of the services are, of course dependent on client requirement and the sort of commercial implications highlighted previously. Therefore, as with all procurement, a significant part of the procedure should be the thorough and complete identification of client requirement. We all know that this can be defined in terms of time, cost and quality but often procurement decisions are made on the most cursory assessment of these attributes e.g. we must build as quickly as possible therefore we can not use Bills of Quantities (not true). In the rush to break ground on site, the broader picture is lost.

Of course, time, cost and quality are important on all projects and all projects should provide value for money as quickly as possible and it may be useful to remind ourselves here of the practices within the Japanese construction industry. A very significant amount of time is spent in Japan on programming and planning projects down to the finest detail. Only when this has been satisfactorily completed does construction start. It is interesting to note that Japanese projects are almost always completed on or ahead of time and whilst it is unclear whether the construction itself is cheaper, time is money for the clients and so cost is a factor (Bennett et al 1987).

- The identification of design procedure.

For any procurement system to be successful, a clearly defined set of responsibilities for the incorporation of the M&E design must be developed. If the definition of these responsibilities can be an industry standard so much the better as the more familiar the parties are with documentation the less mistakes will be made, prices reduced and time saved. Parsloe (1994) has already undertaken much work in this direction and produced a report that could easily be used with the ACE (Association of Consulting Engineers) conditions for the procurement of the design. An example of where this principle was successfully applied was cited by Watts albeit relating to cladding rather than M&E works. Costs equating to 20,000 drawing hours were saved during the design of the Ludgate project (London) by determining the point at which the architectural design ceased and the use of standard manufacturers details commenced.

- The integration of design - interfaces, co-ordination, buildability

The integration of design is becoming more important as technology advances and the internal environment and energy efficiency become issues. Most construction can be split into the three constituent parts of structure, fabric and services. It is vital therefore that these three parts be fully integrated. This will only be achieved if all three are given equal importance during design rather than attention focused on the fabric. In order to fully integrate all three interfaces, co-ordination and buildability must be considered. Again, a systematic framework within which to consider these should be developed and can be tied into to the definition of design responsibilities. Buildability is best achieved (according to Murray) by the integration of design and construction. So integration can be considered on two fronts, the integration of the design of the three main constituent parts and the integration of the design with construction.

ICI Pharmaceuticals (now ZENICA) recognise the co-ordination of the services as a separate operation to design and have commissioned co-ordination detailing and management individually. A further example of the successful handling of co-ordination and integration can be seen on the Sheffield Light Railway project. Substantial savings, in the order of hundreds of thousands of pounds, have been made by dedicating a designer solely to drawing out the duct crossings and co-ordinating the substantial signalling services at the road crossings.
Planning
The biggest cost savings result from early and careful planning of M&E services (Hoare 1993) but its effect may be reduced if a proper design programme is not produced. Davis (1994) believes that the programme for supply, delivery to site, construction and commissioning should be developed during the design phase and be taken into account during all sorts of decision stages. He claims that the involvement of the key parties in the evolution of the programme prevents it becoming a "contractual football".

Prefabrication
Innovative manufacturing techniques offer much to the construction industry in terms of improving product quality by prefabrication, and savings in time and cost due to off-site factory mass production. This is especially true for building services. But prefabrication offers more than direct savings in time and cost and guaranteed quality. The process of prefabrication is, by necessity, fully designed in detail and therefore can also contribute much to the design process. Any definition of design responsibilities will be incomplete unless it takes these availability of manufacturers standard design details into account.

Transparency of price
Good working relationships depend on trust and openness and nowhere is this more significant than in openness of price. Whilst the new SEACC (specialist engineering and construction contract) published by the Electrical Contractors Association requires transparency of payment to the construction and specialist contractors (Papworth 1994), more can be done to provide transparency in the other direction. Peter Rogers of Stanhope Properties is quoted by d'Arcy (1994) as believing that commercially sensitive information doesn't exist. It is rather a case of the industry being frightened to reveal pricing mechanisms in case they expose inefficiencies and non-productivity.

If the specialist contractor is to be brought in early in the design phase, then a clearly defined mechanism upon which the works can subsequently be priced must be established at the outset. It is possible to do this in competition or by negotiation. Two stage tendering of this kind is a well established practice (NJCC 1983). The Construction Management Forum have taken this further by establishing principles of pricing for use in two stage M&E tenders under the headings of equipment, materials, labour, sub-contractors, preliminaries and on-costs and profit (Davis 1994). The transparency achieved by such pricing mechanisms laid down at a very early stage in the project allow value to be assessed and incorporated.

An alternative to two stage tendering is the use of a Guaranteed Maximum Price (GMP). This was strongly advocated by Murray as a method of providing the client with price security whilst building upon the good working relationships required to operate the open book costing system. The GMP would normally include a fixed price for the construction along with PC sums. It may also include for design and cost advice. Any savings made are split between the contractor and the client thus providing and incentive for efficiency from both parties.

Contractor selection
Building engineering services are highly specialised and advances in technology rapid. It is therefore essential that the area of expertise of the contractor matches the services required. The more the project depends upon the individual technical and managerial contribution of the specialist contractor, the more their design, value engineering and management capabilities should be scrutinised and weighed in the selection process. (Davis 1994)

Costs-in-use/service contracts
Existing procurement systems do not allow for the consideration of costs-in-use and the contribution they makes to the value of the services. The term cost-in-use is used in preference to life cycle cost as in many clients find the consideration of the life cycle onerous. What is meant here is the incorporation into the project of the installing contractors liability for the system for a specified period of time, for example 15 years. This liability would mean the cost of running and maintaining systems would become part of the initial tender cost. Although this is not yet a feature of any known contract, Groom expects this to be commonplace within the next five years (Hoare 1993)
Conclusion

The main conclusion of this small study is that there is still much to be done to encourage the various parties of the construction industry to work together for the provision of a product that meets the clients priorities. Although most parties will claim that they are indeed doing just this, a fundamental change in attitude is required for improvements to be made. That there is scope for improvement is not in doubt. In his paper, Davis (1994) outlines where he believes the industry can target savings of some 20% on building engineering services by following many of the steps discussed here.

The changes must not only come from the contracting side, but also from the client. A much more open approach to construction procurement is needed and this stems from greater knowledge of the processes involved. The tools already exist within current documentation what is required is that they are used to their fullest potential by a flexible approach to procurement.

Considering the broader context of world markets, an optimum procurement system would combine the contractual and cost expertise of the UK industry with the openness and co-operation found in the USA and the planning and programming expertise of Japan.

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