PLANNING AND EXECUTION OF BUSINESS – CENTRED MAINTENANCE FOR PERFECT BUILDINGS IN YEAR 2000

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Summary

Building services maintenance has been a neglected area in many buildings in Hong Kong. It has been traditionally and incorrectly viewed by building owners as an overhead expense that does not have any profit or investment potential, and little emphasis is given to maintenance. M&E services play a greater role in the functioning of intelligent buildings and also effect the efficiency of the business that operates from the building, and quality of life of the occupants working in the building. Fundamental re-thinking of the traditional approach to the maintenance of building services is required to obtain breakthroughs for better building and M&E services, and a business-centred maintenance system is a pragmatic solution.

Introduction

There is a growing awareness that building maintenance has been overlooked and neglected for too long in Hong Kong. Buildings often fail to perform satisfactorily as a result of inadequate attention given to the maintenance aspect from the design, manufacture, construction/installation, testing and commissioning and also the occupation of a building. Thus, many building developers and users are now paying more attention to the quality of maintenance of building service. Nevertheless, the present approach that we use to maintain our building services does not match the users' needs in many cases.

A building consists of three major parts, namely: structure, building element and M&E (or building services) element. In general, building services account for more than 30% of the total cost of a new building. M&E services are the only active component in an otherwise passive shelter. When a building is put into use, services have to perform day in, day out for the life of a building. Modern buildings do not exist if there are no people and business organizations. An organization has a core business function and a number of support facilities (e.g. M&E systems). Obviously, to support these organizations' operations, services must be fully planned and managed from the design of a building, and the installed mechanical and electrical services must operate efficiently, and support the core business function in each of the business organizations that operates from the building. The result will be a better building with better service.

Maintenance is costly, the cost of services maintenance has been demonstrated to represent a considerable proportion of the total building operating costs, possibly on a par with the cost of all utilities. It is necessary to spend no more than it is necessary to meet the business need and the statutory requirements. The building services profession must put much greater emphasis on planning of operation and maintenance.
The aim of this paper is to:

- Address the importance issue of proper management of building services design and installation for better building services maintenance;

- Raise the need for a proper maintenance strategy for business organizations; and
- Give a design-maintenance process protocol based on the RIBA Plan of Work and the CIBSE TM17 maintenance document.

The maintenance needs

There are indications that maintenance is beginning to receive closer attention than at any time in the past, at least in part to the realization that it is a controllable cost, not fixed overhead, and very much allied to the cost of energy.

Maintenance is also responding to:

- More complex building and M&E services design which are usually innovative and sophisticated in nature, and costly to operate and maintain in general;
- Operating building profitably and efficiently;
- More environmental consciousness as a result of more legal obligations;
- Flexibility of internal planning and services capable of responding to a rapidly evolving commercial world;
- More competitive property market requiring better building performance and M&E services in order to attract users and tenants;
- Standards of buildings are constantly rising, making it necessary to improve the building's standard to match that of more modern properties in order to maintain the interest of tenants and the needs of those businesses that are operating from the building;
- Most building owners/users are now more demanding and require better buildings which can support their business at all times; and
- Higher reliability of building services and user friendliness.

How can we as engineers serve our demanding clients? The answer must be better design, installation and maintenance. Furthermore, if we do not care for the facilities we have now, then it is unlikely that we will be able to look after the more sophisticated new facilities as they are added to our portfolios.

Cost of maintenance

The main costs of maintenance can be classified under three headings; servicing, fault finding, and repairing or replacement. Anything which reduces any of these aspects of maintenance will save money. Obviously, it is not possible to eliminate all maintenance for all the building services in a building even at any cost, but it is a factor that can be included in a life cycle cost comparison. If it is not possible to convince a client that a high initial capital cost should be expended on the basis of a lifetime of saving or profit from that plant or the maintenance cannot be designed out then further choices must be made.

Maintenance of building services is costly. The increasing competition in the market place and the long-term building economy have forced property owners to cut costs, improve maintenance efficiency, extend overhaul periods, reduce equipment downtime and protect the business organizations, have meant that we engineers have to look for better approaches to the maintenance of building services plant for attaining a better and more profitable building.

Evolution of building design/maintenance

Maintenance of building services plant is part of a building design. To understand the necessity of a new approach to their maintenance, a quick review of the evolution of building design is helpful.

Since 1960, the process of change in the building services industry has be identified to have three stages in Hong Kong.

i. Stage One (1960 – 1970)

- Simple building
- Simple building services
- Over-designed systems; more reliable and easy to repair
- Maintenance skill was lower than it is today
- Preventive maintenance was not a high priority
- Cheaper fuel and labour costs

As a result, systematic building services maintenance management was not used. Furthermore, building services designs were simpler and straightforward. The concept of strategic maintenance for the continuity of a business organization was new.

ii. Stage Two (1970 – 1985)

- Buidings were bigger and more complex
- Complex M&E services
- Higher costs of maintaining M&E services for highly serviced buildings
- Higher fuel costs
- Clients began to demand better service, higher plant availability, longer equipment life and lower costs

In order to satisfy the building owners in view of the escalating maintenance costs and the need for better buildings and their building services, this led to the growth of maintenance planning and management. Scheduled maintenance was usually the norm. Services designs were of course, becoming more complex in nature. However, maintenance aspect was still based on the traditional tactical practice – maintenance takes little or no account its condition or its contribution to the overall purpose of those business organizations within the building.

iii. Stage Three (1985 – 2000)

- More complex and larger buildings and infrastructures
- More use of IT
- High expectation from building owners and users
- Increasing reliance is being placed on building services to provide more demanding building performance
- Greater health, safety and green building issues
- Higher plant availability and reliability, and longer equipment life would be expected
- Higher maintenance skills and more managerial issues are required
- Greater cost effectiveness with the constraint of the still rising cost of maintenance
- More stringent statutory regulations requiring more attention to be given to the control of building and its building services

- Tight budget and limited resources for building construction

As buildings more towards a greater dependence on M&E services to provide the comfort, conditions and facilities expected by their occupants, there will be an increasing need for competent maintenance professions and proficient building services maintenance management. Building services design and installation are obviously more complex than the stage two outlined earlier. The maintenance responsibility will be made more difficult as the more use of sophisticated engineering services technology becomes more widespread in buildings. This also means that the customary skills associated with building services will need to be re-assessed to ensure that they are in tune with the increasing variety of technically advanced engineering services to be found in all modern and highly serviced buildings.

Furthermore, the issues of energy conservation and environmental protection are expected to play more significant roles in building design, installation and maintenance.

Building owners and operators strive to make their buildings and engineering services more energy efficient. This will mean that, in addition to improved levels of insulation, better controls and higher performance plant will become more commonplace. To continue to achieve maximum output for minimum energy input there will be an increasing onus placed on maintenance for more frequent inspection and performance monitoring. However, the onus should also put on the designer's shoulder too as maintenance is part of a design. If the services design is imperfect, the subsequent maintenance is much harder.

Many current maintenance systems are based on work priorities decided subjectively on the principle of 'least risk of failure'. Although such an approach reduces the likelihood of serious breakdowns, it does not identify how much maintenance work could safely be reduced. A changing technological attitude to maintenance has created the need for information on working conditions, levels of risk associated with particular plant and its applications, the preparation of the necessary data and the application of it to failure modes and effects analyses. This in turn could influence future design and help to integrate better the design-maintenance relationship.

iii. *The New Stage after Year 2000*

There are indications that maintenance is beginning to receive closer attention than at any time in the past, at least in part to the realization that it is a controllable cost, not a fixed overhead, and very much allied to the cost of energy.

The changing design/maintenance techniques include:

- More complex building design, where designs are no longer standard, some may be very innovative and sophisticated;
- Focusing on business / customer as maintenance is 'done to' the physical assets or facilities. But these facilities exist only to fulfil the occupier's business plan. In most cases, that fulfillment is achieved by delivering services to the people who run the business;
- Designing M&E services with a much greater emphasis on reliability and maintainability, energy efficiency and better working environments;
- The use of strategic building services maintenance management rather than tactical;
- The use of new maintenance techniques such as conditioning monitoring;
- The asset must be modified to meet rising expectations and new statutory requirements;

- Operating buildings energy efficiently;
- More environmental consciousness; and
- A major shift in organizational thinking towards participation and teamworking – maintenance team is no longer separated from the design and construction team, all will participate and provide the best systems in consistent with the building economy.

In a nutshell, the key challenges facing modern maintenance engineers can be summarized as follows:

- To fulfil all the expectations of the owners of the assets as well as the users of the assets and the business organizations that operate from the building;
- To select the most appropriate maintenance techniques which meet the business needs of an organization;
- To deal with each type of failure process with regard to the impact on the business function of an organization;
- In the most cost-effective way and the push for 'more for less workdone'; and
- Continuing improvements in maintenance based on both ongoing and long-term maintenance in order to maintain the original standard and the constantly rising standards of new buildings in the same market sector.

The concept of business centred maintenance

The approach to the formulation of this rational maintenance strategy derives its impetus from the identified business objective of a business organization within the building that we are looking after. The concept also stems from the well-known quality management system. In brief, building services maintenance is a support service. In order to satisfy our customers (i.e. the business organizations and people), the support service must support the key business activities. For good service, maintenance must be planned and effectively carried out so that the customer's interest is taken care, and also as a first priority. Planning must start by identifying the services (M&E systems) to support the enterprise/operation. In addition, the user's requirements, possible consequential effect on business as a result of failure of M&E services, and the dimension of service quality must fully be identified, evaluated and engineered.

If the M&E services systems and our management of building services maintenance can maintain and enhance the identified needs of the operation of the business organization, the building would be classified as a high quality building. Naturally, both building users and building owners would benefit directly and indirectly, as a result of:

- Continuity of business function as services are perfectly designed and maintained;
- Minimum risk to the business function of a business organization as all possible risks have been identified and allowed for in building services design and maintenance; and
- Good service will be provided to meet user requirements/needs, and the building would become a profitable building since the good delivery of service provided will be the user's important requirement when they decide to rent a particular building.

All in all, this business centred maintenance is a pragmatic approach, and can be used for both new and existing facilities. However, it must be pointed out that the application of this concept could be difficult in certain existing buildings in which the original designs of the M&E services will not match the users' needs in first place. Of course, as a stated problem is half-solved

problem, building services engineers can still improve these existing buildings, perhaps, with greater difficulties and may have to use compromise solutions in view of the site constraints.

Design and Maintenance

It is essential when examining any subject in detail, for a definition to be first provided. Design, which the Concise Oxford Dictionary states is – to destine for a service; to contrive; to plan; to purpose; to intend – and it would seem obvious that if a designer contrives and plans, that the purpose or intention of his planning shall in the ultimate be the absolute goal of everyone concerned.

As far as building services design is concerned, design therefore can be said to be the concise planning with a purpose and intention of creating the means to provide by electrical, mechanical and equipment for use in buildings. In order to enable all building services to work satisfactorily, maintenance is necessary. Therefore, maintenance is part of design.

What is maintenance? The Oxford English Dictionary defines Maintenance as – to keep in order, serviceable, proper condition or repair. DESIGN to destine for a service: MAINTENANCE to keep in order, serviceable. Can it be said therefore that the two functions of Design and Maintenance are in fact complementary, and if so how are they complementary? Should the designer design for efficient operation of the plant or equipment with which he is concerned and completely disregard maintenance; should he design plant or equipment for maintenance even though the functional performance might leave much to be desired, or should he in fact endeavour to bring together these two ideals?

It is, of course, in the latter phase that the key, and indeed the whole answer to efficiency and economy lies in as much that good design is in itself maintenance, and non-maintenance is a project of good design.

However, a third factor enters the picture at this stage, one which is not unfamiliar to either designers or maintenance engineers – the common denominator finance.

Design and installation

In large buildings with complex services, the services installations may represent half the capital investment apart from the cost of the space to house them. The running cost is a major factor in the cost-in-use of the building, and efficient operation without breakdowns is essential to the comfort and work of the occupants. It is clear that designers of modern, heavily serviced buildings should regard adequate facilities for maintenance as among their primary responsibilities. Ideally, designers should develop buildings which require little maintenance during their proper operation and facilitate ease of maintenance by virtue of design.

The primary consideration of a building design is the production of a functional facility as a new or changing need for an organization. Since the functional requirement drives the design, there is a tendency to concentrate on this aspect of the design at the expense of other consideration, especially since maintenance is the last thing on the designer’s mind. However, the conceptual phase of a design is the single point in time at which there is total control over the future maintenance and operating cost of the facility. The ability to control or modify maintenance diminishes from the earliest step in the design process as shown in table below.

Control over maintenance during the life of a project

STAGE	CONTROL
Concept	*Total control* – building and services can be tailored to any maintenance philosophy; designing out maintenance will eliminate most problems.
Design	*Total control* - flexibility remains to select systems which have low maintenance requirements.
Construction	*Very limited control* – design is fixed; difficult to change design but still possible at high cost; inspection will identify maintenance problems (not ALL).
Building in use (a life of) 50 to 60 years	*No control* – maintenance problems will develop and appear. Repair – very limited control, minor corrections to maintenance is possible. Replacement – still limited control, but can reduce on-going problems Improvement/modification – control flexible is a little bit better, but may give good control (NOT TOTAL unless the whole system can be changed).

Therefore, the best answer must be maintenance by better design. If we address the problem of maintenance after handover, then I would say that is far too late and it is extremely difficult and expensive to overcome maintenance problems such as:

- Eroded value of asset due to poor building performance (supported by M&E services);
- Possibly more health and safety problems;
- Loss of productivity through illness, degraded products as a result of unsatisfactory indoor environment; and
- Loss of rental income as a result of poor quality building.

For perfect building, maintenance should be considered as an integral part of the project during all phases of the design, and, preferably, during the preparation of the brief. Designing out maintenance should be adopted as much as possible. The management of building services maintenance, the reasons for such maintenance and its implementation need to be clearly defined. It is no longer acceptable to relegate building services maintenance to a peripheral activity outside the main business management stream. Maintenance of the M&E services required to support the business function of an organization must be fully considered. Furthermore, services have to retain their design performance by proper maintenance. Otherwise, business efficiency and profitability will both suffer if the performance is below an acceptable limit.

With the increasing complexity of modern services, it is more essential than ever that the engineering and architectural aspects of a project are developed simultaneously from their inception. The types of services installation to be used should be identified before the overall architectural design is finalized and the necessary services systems/plant determined. It is generally agreed that the earlier a detailed study of maintenance is carried out, the greater the opportunity for lowering cost and/or improving maintenance quality. In fact, this concept obeys the Pareto Law that 80% of the maintenance cost is contained in 20% of the design elements (i.e. early stage of a project) because it is here that the greatest value mismatches (inadequate maintainability) are likely to appear.

At the outset of a project, the following questions should be considered by the design team:

- Does design meets the business function of the organization?
- Is the plant too large? too small? or uneconomical?
- Does design increase or decrease service requirement?
- Has a risk assessment of the failure of the building services plant been done?
- What are the implications on running costs? maintenance costs? and replacement costs?
- Are proposed services essential? desirable? or unnecessary?
- How reliable are the services?

If all these questions have been well considered, many of the design features which can have an adverse impact on maintainability can be avoided or eliminated, or the maintainability can be considerably enhanced without necessarily increasing costs (by value engineering); where increased first cost cannot be avoided, the increase can be demonstrated to have investment potential in more efficient energy utilization and longevity of the services systems.
The designer must consider that buildings differ in their use, the level of service that the client requires, the amount of money available for maintenance, the quality of operative available to carry out the work and most important of all, the role that the equipment plays in the particular system in which it is installed. For each and every item of plant, the importance of the plant in respect of the functioning of the system as a whole must be examined. The development of the design with maintenance must be a procedure of examining each plant item to assess how critical it is to the whole operation, availability required and where appropriate the modes and probability of failure. To determine the importance and required availability of the plant, the consequences of failure must be considered.

The designer would do well in the early stages of his planning to consider the technical information pertaining to defects and maintainability and to ensure that his design is satisfactory, that its running is effective and its maintenance is economical.

Very often no channel of communication whatever exists which enables the maintenance engineer to feed back to the designer any observations which might be useful in assessing the difference between design effectiveness and practicability. Also, of course, it should be realized that feed back of information and acceptance of knowledge is useless unless further action is taken to apply this disciplined advice and transform it into action and interpretation of future design. If the designer can seek the views of the maintenance engineer who has a wealth of experience and know-how to offer in the right time, this can serve to improve the design of proposed plant and equipment, both with regard to efficiency, economy, and general utilization.

How important is building maintenance?

The following schedule shows a rough split of the major costs-in-use per annum for a typical non-domestic building:

Items	Percentage
Energy	25 - 35
Maintenance	15 - 25
Cleaning/Caretaking	15 - 30
Rates	5 - ?
Insurance	2 - ?
Security and management salary	0 – 10

The energy and maintenance costs can be a significant item of expenditure. Also, the cost of maintenance of the building services and the utilities can rapidly exceed the original capital investment in the services. Over the life of a building, this component part of the operating costs of a building will be several multiples of the original investment. Thus, measures designed to optimize energy consumption, maintenance, and cleaning and caretaking costs, may impinge upon three-quarters of the running costs. Improvements will also provide considerable cost benefits over the life of the services systems, and can result in improved building performance.

Low levels of maintenance commitment have a detrimental effect on the sale or rental value of the new property. If the original design of a building may be restrained by a low capital budget allowance, the result is often a cheaper initial construction, which can later be heavily saturated by revenue maintenance budgets for expensive repair, maintenance and possibly additional works that have been made necessary by the financial restraints made at the earlier design and construction stages. Obviously, it is clearly a case of false economy.

Why do we maintain buildings?

Until recently a building was seldom considered to be an asset or a resources to the property owner or user company. As the cost of land and building escalated, so did the awareness on the part of both property owners and users that their buildings provided more than just a space within which they could operate a business or manufacture a product. With such an awareness developed a new term in property management: “asset management”. This means the effect of value of a building to its owner or user.

Like any other asset, a building needs protection and regular maintenance if it is to continue to be an asset, a fact all too often ignored, with unfortunate economic consequences.

A building and its building services can therefore be viewed as either an asset or a resource.

i. Asset. The building owner may consider its value in two ways:

   a) As a capital asset, whereby he receives a financial return on his investment.
      Here the owner must ensure that he prevents a loss of income occurring through the loss of rents or production resulting from failure in performance or loss of certain facilities within the building due to lack of maintenance.

   b) The capital value of the property if the owner were to sell, which he must protect from depreciation and loss of value. A reduction in the capital value of a building may result from:
      - Deterioration of the building and its building services from lack of maintenance;
      - Fall in the property market as a result of poor utilization of the asset; and
      - Redundancy (inflexible designs cannot cope with future adaptation of the building).

ii. Resource. A building and its services may also be viewed as a resource for the production of a product by manufacture, commercial service or health / educational service.
   The owner/user of the property will need to regularly maintain the building and its services so as not to incur the loss of production of a product or service because facilities within the building or site have become inoperative or defective.

   Most of the buildings will be used to generate rental incomes. Business organizations are the major users in these buildings. Therefore, it is clear that all M&E services required to support

the business functions of these organizations must be managed to run smoothly. A failure or breakdown in any of the M&E services plants or systems will definitely affect these business organizations, and the financial losses can be very high. Hence, the correct maintenance techniques must be used, and any failure of the M&E services plant would result in minimum impact on the core business of an organization. Therefore for this business centred maintenance system, one should:

- Treat the core business of an organization as the first priority;
- Design the M&E services to satisfy a particular building, and additionally, the services systems must also satisfy the needs of the business organization that operate from the building;
- Consider the consequences of business interruption as a result of failure of the M&E services;
- Evaluate the failure mode of the M&E services serving the organization;
- Find ways to limit or stop the failure by design and management of services maintenance; and
- Consider the use of performance based maintenance based on rigorous approach to subjective as well as objective feedback.

Obviously, maintenance people have to adopt new ways of thinking and working, as engineers and as facilities managers so that they can deliver the best service in building services maintenance. But this may not prove to be easy.

The parties concerned with maintenance

If all the above points in relation to the changing face of our maintenance world are examined in building services term, it is the design of the equipment that the building services designer selects, and the way in which it is incorporated into systems that dictates the quality of maintenance.

The maintenance requirement are directly a function of the actions (and omissions) of the building owner, building services designer, manufacturers, installers and maintenance engineer. The building owner obviously has a role to play, in the maintenance function within the building owner's organizational structure. He will dictate the policies chosen, the amount of investment in maintenance, and the eventual quality of maintenance that will be achieved.

Thus the requirement of quality maintenance places great responsibility upon the five main parties involved in any building project:

Party	Activity/Function
Client	Quality of briefing-planned usage of building; comprehensive and clear maintenance requirements in relation to business need
Designers	Quality of design process-adequate, accurate and constructable and maintenance is a 'built-in' in design
Contractors	Quality of M&E services installation and construction process-conformance to requirements, good workmanship and adequately tested and commissioned.
Manufacturer	Quality of products-high quality and easily maintained
Maintenance-engineer	Quality of maintenance of building-functional building based on effective management of maintenance

As seen from the above, maintenance is every party's concern as all activities are interlocked together. It is clear that for best result, a team approach is necessary to carryout all these interrelated and interacted activities which have to be undertaken by each of these five parties as an integrating unit as:

- The client's contribution can influence the services designer's design and other subsequent activities;
- The designer's design can influence the physical installation of M&E services, their performance and requirements of maintenance; and
- The contractor's working and expertise advice can affect the decision-making process of design and management of installation and subsequent maintenance.

Quality of services design and contractor's decision on practicality, constructability and cost can all influence the manufacture of M&E services products or components; services design and installation can have significant impact on the management of maintenance of M&E services, and thus the usefulness of the building. Recognizing the inherent complexity of the M&E services design and the relationships between the five parties as stated above, it is quite possible that things can go wrong if there is a lack of structured quality management for design and construction. Clearly, the knock-on effect created in one activity can have significant impact on the subsequent activities or events, i.e. inadequate design produces unsatisfactory installation; unsound installation requires more maintenance of services, and as a result these chain actions can finally effect the quality of a building. Nevertheless, the most important role is that of the designer. And he has a professional responsibility to design out maintenance and/or make suitable provisions for maintenance.

The separation of design and maintenance and its re-convergence

Unfortunately, maintenance and design are frequently treated as if these two activities were unconnected. In other words, if building services are not fully integrated with maintenance, one can easily find that:

- The building services systems do not perform satisfactorily as they cannot be easily maintained and result in lower operating efficiencies;
- The building does not perform satisfactorily since a building cannot work by itself. Services are needed to support the normal or special functions of the building enclosure; and
- The efficiency, convenience, life span, economic viability and appearance of the asset will be seriously affected.

The maintenance characteristics of buildings are indeed a result of the original design process. Surely, good design with sufficient maintainability yields good buildings. In addition inefficient designs, inadequate specifications, poor workmanship and inadequate testing and commissioning can all result in faults and maintenance problems which are subsequently often difficult and usually expensive to diagnose and remedy.

Few design engineers have had extensive experience in designing for maintainability. At the same time, building owners often place undue emphasis on initial costs and ignore the annual cost of repair and replacement. In many cases the evidence gained from detailed surveys suggests that maintenance is generally carried out as a series of ad hoc and unrelated compromises between the physical needs of a building and the availability of finance to the owner or user.

Building and M&E services start to ‘age’ or deteriorate from the moment they are completed and from that time onwards need maintenance in order to keep them in good condition. Gradual deterioration is inevitable, but the speed at which it proceeds can be regulated and the ultimate failure of the building and M&E services, in whole or in part can be avoided, delayed or even accelerated according to the way in which it is designed. This, in turn is to a large degree conditioned by maintenance provided and the ease with which the essential maintenance task can be carried out.

Besides, the quality of maintenance achievable has a direct bearing on the energy efficiency of the building services systems and with energy prices set to increase dramatically in the next decade, this will be of increasing importance.

Obviously, the design engineer should offer a range of options that match the intended use of the building, allow efficient day-to-day maintenance, consider economical cost in use and allow a plant replacement programme to be developed for the intended installation.

To have a quality maintenance system, maintenance should be considered as an integral part of the project during all phases of the design and, preferably, during the preparation of the briefing stage. For best result, the management of building services maintenance, the reasons for such maintenance and its implementation need to be clearly defined and clarified between the owner and his building services designer. It is no longer acceptable to relegate building services maintenance to a peripheral activity outside the main business management stream.

Over the whole life of a plant, the maintenance costs can equal the original capital costs. When fuel costs are also included, the total operating costs can be significantly more. For this reason the full implication of system selection need to be carefully assessed and decisions taken with the aim of:

- Ensuring that a building and its services continue to function reliably, efficiently and effectively;
- Reducing the overall life-cycle costs;
- Reducing unnecessary maintenance work (by designing out maintenance) and expenditures; and
- Reducing the long-term maintenance costs throughout the expected life span of the system.

The energy-efficient design of buildings requires an understanding of the way in which occupants use spaces and facilities whilst remaining sympathetic to the constraints of cost, methods and buildability. The solutions to the problems of energy efficiency are still being evolved, and we should continue to be aware of the progress that has, and is, being made. The separation of the building services design logic and building services maintenance management and the energy conservation logic is no longer tolerable, and designers and maintenance engineers must discipline themselves to accept the interdependence of these concepts.

As stated previously, the building services engineer will exert the greatest influence over the eventual maintainability of the building services installation. However, it is often the case that their ability to perform this important function is impaired by their own lack of knowledge and understanding of maintenance requirements, and also by the terms of engagement under which they are often employed. It is also true that commercial and/or contractual pressures and constraints limit the influence that can be exerted. The problem of the lack of awareness of maintenance problems can be tackled by using feedback/information from the maintenance

engineers or maintenance contractors. Maintenance and operation provide a wealth of information, that, when properly fed back into the design process, will improve design and subsequent maintenance significantly. Of course, building services courses should put greater emphasis on the maintenance engineering. Also, practicing engineers should make good use of CPD courses. Most importantly, services designers must conduct design audits based on their building services installation, otherwise, it is difficult to master the maintenance aspects of system design.

An integrated approach to maintenance

Modern buildings are designed to meet more complicated needs than those of previous time; improved space standards, higher environmental standards and new pattern of use of building can effect their design and construction. The natural result of these changes is higher building standards and more complicated buildings. This means that (1) increasing reliance is being placed on M&E services to provide the environment and the facilities needed, (2) there is a growing need to ensure services are available when required, operated at an expected level of efficiency, and (3) the design influence on the maintenance of all building is greater than ever before. Those responsible for managing the maintenance of buildings and their engineering services need to have both management ability and technical expertise as design and maintenance can no longer be treated in isolation.

To best serve our customer, we have to adopt a rational approach to the management of services design, installation and maintenance. In brief, the essential processes are:

i. For the designer

- Identify and evaluate client's requirement and business needs;
- Develop the maintenance objectives and a stated maintenance policy within which decisions on maintenance are taken;
- Prepare best system design that fits the building, the business that operates from the building and the users;
- Design for manageability, maintainability, operability and flexibility in conjunction with detailed analysis of the effects affecting the proper operation of those organizations within the building;
- Select the most reliable services to match the failure mode of the building services plant;
- Integrate maintenance into design with useful feedback from maintenance engineers, contractors and specialist commissioning engineers;
- Adopt the concept of designing out maintenance as much as possible;
- Review design with maintenance personnel (Maintenance can be made easier if appropriate facilities are designed into the system. Furthermore, correct specification of instrumentation and monitoring devices can give the maintenance engineer an important diagnostic tool when assessing system failures.)
- Evaluate reliability and maintainability by maintenance engineering principles, value engineering and life-cycle-costing;
- Prepare detailed specifications and programmes pertaining to testing, commissioning and subsequent maintenance;
- Supervise M&E services installation and give due consideration to maintenance requirements, and make sure all services meet the design;
- Monitor very closely the testing and commissioning with the maintenance engineer and identify critical operational and maintenance problems;

- Improve maintainability before final handover;
- Complete all O&M manuals with all the contractors and the maintenance engineer;
- Prepare projections of all energy performance and running costs (benchmarks!);
- Prepare operational characteristics, contingency plans and maintenance systems and detailed maintenance documentation for the maintenance engineer; and
- Provide additional consultant service on maintenance.

ii. For the contractors

- Understand client's maintenance objectives;
- Integrate maintenance into installation of services;
- Use best workmanship and good quality plant and component;
- Improvement in design/installation for better maintainability;
- Prepare adequate O&M manuals well in advance with the consultant;
- Perform complete testing and commissioning; all commissioning details are adequately documented and accessible and arranged for easy use to diagnose problems; and
- Operate/maintain the plant with the maintenance engineer/the consultant.

iii. For the maintenance engineer

- Understand client's maintenance objectives and the requisite priorities;
- Understand the maintenance needs of the organization to serve the business function
- Understand all M&E services systems;
- Identify maintenance resources and budget, reduce maintenance work as much as possible by condition based planned maintenance system;
- Use strategic maintenance rather than tactical; select the maintenance technique to match the failure mode of the building services plant and to meet the business needs of an organization;
- Provide comprehensive building services maintenance management;
- Use performance based maintenance system;
- Prepare contingency plans for the business need;
- Provide adequate operation and maintenance audits for improvements in service to be provided;
- Feedback to the consultant for improvement in system performance; and
- Consider out-sourcing if necessary in order to provide best service.

With increasing legislation affecting building services and the need to demonstrate cost-effective maintenance, the foregoing gives a brief insight into stages and the details involved in implementing successful maintenance management.

There is no standard maintenance strategy that will suit every application. Each building, its design and method of operation, will effect in different measures, the maintenance strategy to be adopted.

Whichever of the choices is chosen, a successful maintenance operation will still require good management of design, installation, testing and commissioning, and last but not least, proper planning of maintenance with due regard to the business that operates within one's building.

A pragmatic approach to maintenance – the design/maintenance process protocol

Building services maintenance is a process which can be broken down into appropriate activities from the design stage to the end of a building project.

The principle of the process protocol can be summarised as a model which is capable of representing the diverse interests of all the parties involved in the design, installation and maintenance of a building. Basically, the entire process has to cover the whole life of the project. This approach ensures that all the maintenance issues are fully considered from both a business and a technical point of view.

In Hong Kong, all building services engineers have used the RIBA Plan of Work (developed by the Royal Institute of British Architects) for most of their building design projects. The RIBA Plan of Work could be rewritten to show the various stages involved in the maintenance situation. This could be a vital document for consultants by demonstrating both to clients and contractors the processes needing to be undertaken to achieve successful maintenance.

The protocol provides a framework for managing building services maintenance. Since the maintenance process must not be separated from the design and construction process, the protocol has to cover the whole life of a project. The key features of the maintenance protocol are as follows:

- Maintenance is related to the business of a facility, this ensures that the operation of the M&E service can satisfy the operation of the facility;
- Maintenance has to be designed out and incorporated into the design and construction process by all parties;
- Maintenance needs to be planned, organized and managed in each phase of the RIBA Plan of Work; and
- Maintenance plan has to be analysed, assessed by technical evaluation, and reviewed before and after each phase of the RIBA Plan of Work.

The RIBA Plan of Work (Source: Project Management Handbook for Building Services, BSRIA) does not show the maintenance plan under the activity zone of Facility Management. To bring back the missing design and maintenance as an integral system, the author has constructed a maintenance protocol. The protocol shows the important maintenance activities that would be considered and completed in each stage. The deliverables from each stage must be evaluated, reviewed and agreed before moving into the next stage. For best maintenance strategy, the protocol must be flexible, but change must be controlled to achieve a 'balanced' design and maintenance.

The simplified protocol covers:

PHASE	ACTIVITIES
Inception	Prepare maintenance brief
Feasibility	Develop maintenance strategy
Outline proposal	Revise abovementioned items
Scheme design	Full maintenance plan
Detail design	Value Engineering/Revise strategy/maintenance plan
Production information	Finalise co-ordinated maintenance plan and documentation

Construction	Develop operational model, oversee BS installation. Maintenance planning, testing and commissioning.
Building occupation	Maintenance and improvement, and audits

All these activities will involve the design and construction teams (i.e. client/user, BSE engineers, FM manager, BS maintenance engineer and the relevant services contractors) as they are all responsible for ensuring the cost effective management of assets and the creation of an environment that strongly supports the primary objectives of the building owner and/or user. With this protocol, the present fragmented maintenance management can be greatly improved.

As stated, the various activities of design team briefing, design, services installation/building construction, and preparation of maintenance are usually not carried out in a disciplined approach. This is not the right way of working. A disciplined approach is needed. All commissioning and maintenance aspects will have to be carefully evaluated and planned from the documentation stage of the design. All parties should be fully involved in the design of maintainability in each stage of a design/maintenance process protocol as shown below:

- Briefing - Identifying client's brief (use of building and maintenance policy)
  Note future growth of the buildings and the potential users and necessary changes

- Design phase - Designing building in accordance with both of the client's needs as well as those for the organizations within the building
  Plant failure/maintenance risk/organization risk analysis
  Maintenance is to be designed out by the designer
  Planning of maintenance with relevant parties
  Maintenance cost analysis
  Continuing review of design and maintainability

- Tender stage - Analysing contractor's proposed plant and equipment with due regard to maintenance aspects by the design team
  Improvement in maintenance

- Construction stage - Planning of testing and commissioning by all parties
  Planning of maintenance programmes and associated activities by all parties
  Evaluation of system commissioning by all parties

- Building occupation - Maintenance plan by all parties during the defect liability period
  M&E services consultant to continue his service as an aftercare service for best building services maintenance
  Use of performance based maintenance system
  Continuing improvement and analyses

The protocol emphasizes:

- Maintenance is viewed as a support business activity;
- Team working between the client, designer, installer/manufacturers and maintenance engineer to achieve a profitable building;

- Co-operation and co-ordination of design and maintenance aspect as an integral unit;
- A pragmatic approach to maintenance right from the early stage of a design, the concept is based on " Avoiding Maintenance Problems by Design" and design and maintenance must consider the building and its business organizations and the people working within the business units; and
- Maintenance is part of a design, the designer should not treat this as an aftercare service, and every effort should be made to improve the building services maintenance management.

Application of the protocol

This paper describes three case studies. The case studies cover discussions about the use of the proposed design/maintenance protocol for promoting better maintenance of buildings.

Case study No. 1

A 1800 beds hospital requiring improvement in existing medical oxygen installation.

The maintenance engineer and the appointed consultant had evaluated:

- The project characteristics;
- The maintenance needs of the medical gas system to serve the whole hospital (higher occupancy rate in Hong Kong);
- The functional failure of the medical gas supply system;
- The root cause of the failure of the oxygen main supply system;
- The failure consequences; and
- Possible future increases in patients, and changes in use.

After going through all the aforesaid analyses, the consultant had proposed:

- Another oxygen main running from the oxygen bulk supply plant (also includes standby emergency oxygen cylinder manifolds), but arranged to join (as a parallel circuit) the existing riser pipe. By so doing, a failure of one of the buried oxygen main would not affect the essential oxygen supply to the entire hospital. Of course, the two buried oxygen mains would have to be laid in different positions; and
- All new ward floors should not rely on the existing oxygen riser which is too small and not reliable; an additional oxygen riser would be necessary to improve the dependability; all the two risers would also be connected to a modified ring circuit to enhance the availability and reliability of the system. This ensures that any maintenance work done would not interrupt the oxygen supply.

A study of using on-site oxygen manufacture (by concentrator plants) had also been carried out to see whether this new system could enhance the reliability of oxygen supply; reduction of oxygen supply cost, and the impact of this additional plant on maintenance cost. The present worth comparison indicated that the on-site manufacture system was of no advantage as the oxygen supplier could provide a more competitive price and a very satisfactory reliability. However, the concentrator plant could be adopted under certain favourable conditions such as high liquid oxygen cost and the need of higher availability, etc.
This case study demonstrates the concept of choosing the correct design/maintenance technique to meet the functional needs of an existing building.

Case Study No. 2

A new district hospital with sea water condenser cooling water system.

The maintenance engineer and the M&E services consultant had recognized the problems of corrosion effect and fouling by living organisms, and the consequential blockage of the piping system. They also evaluated:

- The importance of proper design and maintenance;
- The continuity of the condensing water supply for the proper functioning of the hospital at all times;
- The root cause o f the failure of the condensing water system; and
- Different designs to overcome the problems.

Finally, a design included:

- Two power supply systems for the condensing water pump house;
- Duplicated sea water treatment systems to reduce living organisms;
- A dual set of water main run from the sea-water pump house to the hospital sit on the hill, i.e. 4 x 600 mm pipework. This would ensure that one set of the main could be used while carrying out maintenance for the other set of piping; and
- Grouped fresh water condensers with fresh water/sea water heat exchangers, thus reducing maintenance tasks further.

The solutions reflect that design and maintenance must be considered right from the beginning of a project, and detailed analysis must be given to the function of an organization and the requisite maintenance technique.

Case Study No. 3

This is a design / maintenance and reliability strategy being adopted by the Hong Kong Government when designing tall buildings. The strategy emphasizes quality services, availability and maintenance aspects.

Apart from the safety performance requirements, at design, system reliability is emphasised. For example, in the electrical design, the design may allow various contingency steps during equipment failure and/or power interruption. Five steps may be involved. Firstly, electricity supply with two end feed may be obtained from the power company. Secondly, allowance can be made in the main electrical schematic for the inter-connection between different power transformers and switchgears during partial power interruption. The third will be the provision of emergency generator both for the essential load and for the power to maintain limited operation. The fourth is to provide dual supply cable network in building. There are two possible arrangements. One will be to divide the floor into zones each fed independently by different cables each having 50% capacity or more. The other will be to provide two cables (each carries 100% load) for each cable connection. This will provide 100% standby but will be more expensive. The last is the provision of battery back-up such as emergency lighting, uninterrupted power supply system, etc.

To enhance utilization, adequate spare capacity should be allowed in the design to cater for the fluctuating demand in different periods and for future changes. The requirements on occupation

safety and health and the safety of the maintenance staff and the workers would also be taken into consideration.

It can be seen from this description that the designer is interested in the uninterrupted power supply for the satisfactory operation of the building and the designer also considers the ease of maintenance.

In short, all these case studies demonstrate that the proposed protocol is a workable framework for both design and maintenance of M&E services.

Conclusion

The role of building services maintenance should be seen as the combination of engineering function and professional management function.

There are indications that maintenance of M&E services is beginning to receive closer attention than at any time in the past in Hong Kong, due at least in part to the realization (1) that effective management of maintenance can bring about many benefits such as efficient and profitable buildings; (2) maintenance is a controllable cost, not a fixed overhead, and can be managed to reduce this large sum of money yet at the same time improving the performance of the building and its M&E services, and (3) very much allied to the cost of energy which is rising rapidly.

The rising expectation of occupants, together with the pressure from business to optimize cost and value, will ensure the growth of the business-centred maintenance with continuous improvements. For the building services engineers this provides a challenge and an opportunity that should not be missed. Approach to maintenance of building services needs to be re-engineered. Through better building services maintenance management with additional operation and maintenance audits, building performances and energy consumption can be analysed and controlled. Utility costs can be reduced without cutting back on building services performance. More importantly, we will have better building for the society.

Traditionally, maintenance is not treated as engineering management, and has been carried out on a periodic basis, regardless of use of equipment, the building and its business organizations. It is not in the interests of any building owners to have such old maintenance system.

As buildings move towards a greater dependence on M&E services to provide the comfort conditions and facilities expected by their occupants, there will be an increasing need for better management of M&E services. Success of implementation of management of services maintenance requires perfect design right from the start of a building project. However, we must not concentrate just on our engineering issue, we should consider our customers – the business organization within a building first.

For the owner of a building, failing to consider maintenance of building services properly is both a foolhardy and wasteful of an asset and, in the long-run, expensive.

The designer can greatly influence the future maintainability of the systems based on the choices of maintenance available, the role the plant and systems play in the efficient, safe, functional and healthy operation of the building, the spaces into which the equipment is installed and its inherent accessibility. The maintainability can be considerably enhanced without necessarily increasing costs.

The existing stock of buildings and their engineering services will need to be maintained until their eventual disposal or refurbishment. A professional approach to their care and management must be accepted as a responsibility by our professional institution. The move from tactical maintenance of services to the strategic operation and maintenance of building services systems is seen to be an improved service. There is no doubt that this trend will continue as more clients and service providers see the benefits. Also, the growth and success of the facilities management industry will increasingly demand a more professional and innovative service from consulting services engineers, maintenance contractors and maintainers. The services professions can help their clients to improve the maintenance.

As a profession and an industry we need to find better ways to improve the maintenance and operation of building services. The designers and maintainers will have to work together and offer the best service to our external and internal customers which in turn should raise the quality and profile of the building services industry.

The building services maintenance management outlined in this paper is a workable solution. But everybody involved in a project must work together. We will not only be more efficient, but we will be in a much better position to meet the client's business needs as well.

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