

DEVELOPMENT OF LIFT AND ESCALATOR MAINTENANCE METHODS

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ABSTRACT

Over the past 30 years, the lift and escalator industry has grown rapidly as a result of the demand for higher buildings and the changing environment. As a result of this, elevator control systems have developed from relay logic to electronic control, where the computerized diagnostic approach is widely applied. The manufacturing of these new products is attributable to the rapid development of new and advanced technology throughout the world.

This paper especially highlights the lift and escalator maintenance strategy, comprising Government regulations, different life cycles of products and parts, quality and safety assurance of maintenance works, education and training of engineers and technical workers, behaviour of users and the different methods of building management etc. These various aspects should be strengthened and subject to enforcement in the future. A strategic plan will be discussed "in depth" in this paper.

1 INTRODUCTION

It is known that new technology has been advancing worldwide in the lift and escalator industry for several decades. To meet the growth of multi and mega storey buildings and at the same time, the demand for more comfortable vertical transportation, new technology must be continually developed. Maintenance becomes a vital element in achieving this. Over the years, many lift and escalator manufacturers and contractors have overlooked the importance of maintenance. Fortunately, this is not the case nowadays. Maintenance is actually an after-sales service, usually demanded by the owners and users.

Maintenance is so important that it can determine the survival or failure of the lift/escalator companies. Therefore a maintenance strategy should be established to optimize the benefits to the companies, the owners as well as the users. In this paper, a wide range of aspects shall be covered in connection with the process of establishing a maintenance strategy. These aspects include:-

- i. development of lift design over the past 30 years
- ii. elements affecting the design of a maintenance strategy
- iii. establishment and implementation of a maintenance strategy
- iv. assessment of a maintenance strategy

Through the investigation of these aspects, it is hoped that appropriate attention will be drawn by the lift/escalator companies in assessing their existing maintenance schemes and the roles played in maintenance. It is noted that the maintenance of escalators is similar to that of lifts, therefore this paper shall only highlight the aspects of lifts. Nevertheless, the following could also be applied to escalator maintenance.

2 DEVELOPMENT OF LIFT DESIGN OVER THE PAST 30 YEARS

In the past 30 years, the demand for more efficient vertical transportation has rapidly increased, particularly for high-rise buildings. An effective vertical transportation system is obviously necessary to meet this demand. Over recent decades, the design of lift systems has kept changing to fulfil the demands of both lift owners and users. The basic

design ranges from AC2 to ACVV motor drive control, with the lift control system being from electrical and electronics design[1] to computerized system implementation. The emergence of an on-line elevator monitoring system[2,3] provides evidence of this recent development. At present, the system with the highest speed in the world uses a VVVF Control System which provides the highest efficiency in energy consumption and also very good passenger comfort[4].

Many advanced technologies relating to the lift systems and design have been developed to meet the enhanced requirements of modern lift systems, Figure 1 summarizes the key components in advanced elevator technology developed over the past few decades[4].

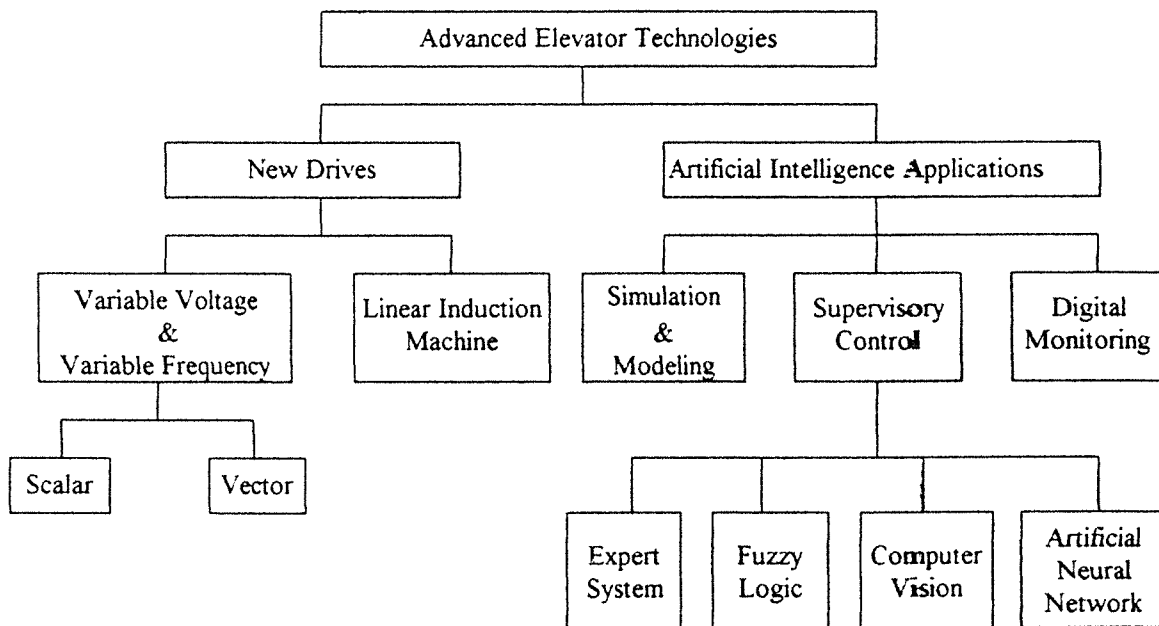


Figure 1

It is a fact that more and more advanced technology will be developed and emerge in the markets in the near future. Lift companies and maintenance personnel must possess this knowledge prior to designing their maintenance strategy. The techniques required for maintenance must develop in parallel with the advances in technology.

3 ELEMENTS AFFECTING THE DESIGN OF A MAINTENANCE STRATEGY

As the technology in lift design changes, there are certain aspects to be considered by the lift companies involved in maintenance, for example, the demand by users for more comfortable travel increases from time to time. There are several elements that must be dealt with during the design of a sound maintenance strategy. These elements include : -

- i. life cycle of components or equipment
- ii. resource requirement
- iii. behavior of building management and users
- iv. quality of maintenance personnel
- v. regulations concerning the lift industry
- vi. action to be taken after the occurrence of an accident

3.1 Life Cycle of Components or Equipment

In undertaking efficient maintenance works, the expected life of each component or item of equipment must be known, in order to arrange pertinent repairs or replacement. Such

knowledge means that unnecessary or excessive works are not undertaken. Apart from the replacement of ordinary components, capital equipment should also be considered as these dominate the cost of a lift system. The issue of replacing or maintaining this capital equipment is always controversial, since the costs involved are difficult to pre-determine. Serious consideration must be made in this respect.

Of course, the causes of damage to components, which may change the life cycle of components or equipment, must be identified so that preventive methods may be designed and implemented in the future. Actually, the causes of lift breakdown can be summarized into two categories, internal and external factors.

Regarding the internal factors, this refers to spontaneous wear or accidental damage of components or equipment. It is known that different parts have 'approximate lifetimes', some are very short, for example, electric contacts and some for many years, for example, main sheave. The lift companies should record the life cycle of all components and equipment and use this data to arrange organized repairs or planned replacement.

External factors mean the characteristics and behaviour of the management staff of the building and passengers. These refer to the 'use' conditions and environment of the lift.

3.2 Resource Requirement

The resource requirement is an important element that should be considered in designing the maintenance strategy. It is obvious that if there are components to be replaced or equipment repaired, spare parts and equipment must be available to do so. The lift company must decide whether to buy, produce or lease premises. This is determined by the number of machines and crew, the size of the workshop that the company owns. Is the workshop capable of producing its own spare parts? Does the workshop possess the capacity for production? Does the workshop have the flexibility to alter or re-arrange the schedule when necessary? All these factors would determine whether the company produces its own components or purchases from outside. The decision made between these two aspects is usually a matter of cost-effectiveness.

3.3 Behaviour of Building Management and Users

Generally speaking, types of buildings can be categorized into four areas: industrial, commercial, residential or multi-purpose. The behaviour of users in different types of buildings and the problems occurring, obviously vary. The maintenance of lifts in these buildings cannot be done properly without the co-operation of the building management or owners, as they are the ones who know their building's peculiarities. No matter how well the lift company implements the maintenance programme, if there is a sudden event or accident, the building management would be the first party to discover this and therefore have the responsibility to immediately make a report to the lift company. Therefore the building management/owners should clearly know and identify their duties and liabilities to manage the lifts in their buildings.

The Duties and Liabilities of the Building Management:-

- i. understand the specification of the lifts and any special features
- ii. recognize the contract requirement between the lift company and the building management
- iii. ensure knowledge of third party insurance coverage by the building management/owner, concerning passengers or others
- iv. monitor the usage condition and environment of the lift operation
- v. apply vandalism control on the user/transportation of workers
- vi. provide clear instructions for the use of the lift to passengers

- vii. meet the local Government's Legislation requirements
- viii. control external factors which affect the lift operation
e.g. fire, water ingress into the lift/pit
- ix. control misuse of the lift for the transportation of inflammable material/liquid,
change of lift "use purpose" from passenger lift to cargo lift
- x. keep good communications with the lift company
- xi. monitor the lift condition

Apart from observing the duties and liabilities, it is very important that positive attitudes of the building management/owners or users are the first priority. Are they willing to spend money to provide good building management? Are they willing to co-operate with each other? These concerns determine whether the maintenance programme can be undertaken successfully.

3.4 Quality of Maintenance Personnel

The lift maintenance works are very labour intensive. The coverage of works include mechanical and electrical installation of lift & escalator equipment and components, regular maintenance and breakdown maintenance, emergency call services, annual testing, overhaul works, testing & commissioning works. Those works are concerned with electrical circuits, electronic circuits, mechanical devices and computer software control etc. As the works performed by the maintenance personnel cover a wide range of areas, a broad technical knowledge must be possessed by the front line technicians involved in the maintenance works. Otherwise, unsafe operations and situations may result.

3.5 Regulations concerning the Lift Industry

One of the major objectives of implementing a sound and comprehensive maintenance programme is to meet the Government's regulations and Codes of Practice. If any regulations are being breached, the results are disastrous e.g. loss of life. Punishment is not simply a fine but it may result in imprisonment. Therefore, during the progress of a maintenance programme, the relevant regulations or standards must be followed. In Hong Kong, there are many regulations and standards concerning lifts[5], not least the liabilities of employer and employee. Figure 2 illustrates those effecting a maintenance programme.

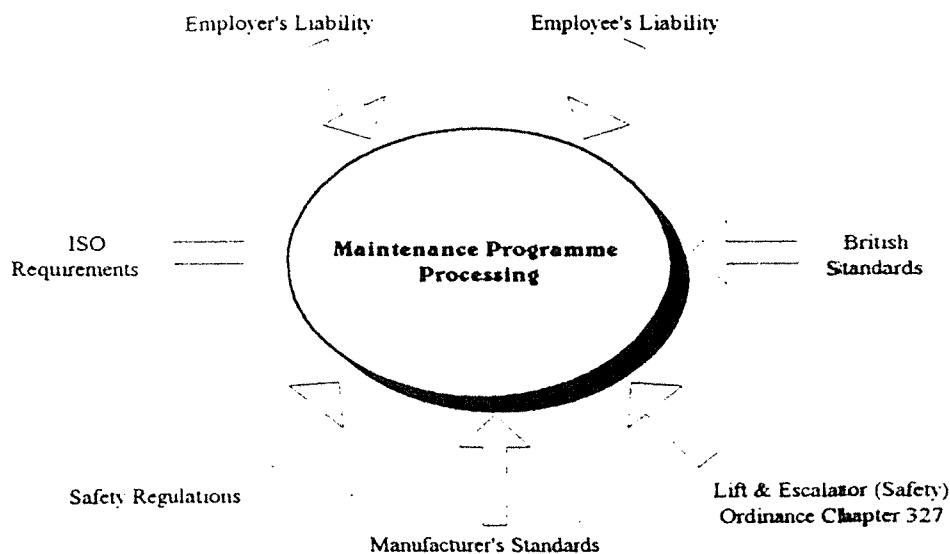


Figure 2

3.6 Action to be taken after the Occurrence of an Accident

After any serious accident has been reported, the Electrical & Mechanical Services Department (EMSD) of the H.K. Government will quickly and thoroughly investigate the causes of the event. A detailed study of each accident, particularly fatal accidents, is deemed necessary to promptly make improvements and prevent similar events happening in the future. The detailed investigation, resulting in a comprehensive accident report is produced to ensure that the lift company understands the actual situation and thereby concentrates on specific items in the maintenance programme. The report from the EMSD enables lift company to identify certain key factors about each injury/fatal case and the accident. These key factors therefore form an analysis which will enable critical cause areas and locations to be exposed. These factors are as follows.

- i. nature of injury / fatal case
- ii. cause(s) of events
- iii. hazardous conditions
- iv. unsafe action
- v. improvement method

Table 1 shows the accidents relating the lift industry that have occurred in recent years. The EMSD has investigated the cause of events shown in Table 1 and issued circulars[6] to all lift companies to remind them of deficiencies and request them to improve the quality of their services.

Date	Location	Description	Injury/Death of person
30/10/96	Braemar Hill Road. North Point, H.K.	A passenger entered the lift at the 17/F, the lift could not stop on the G/F and overran to the lower landing.	Injury: 1 person
30/10/96	Westlands Road. Quarry Bay. H.K.	The weight of cargo inside the lift car could not be detected because the overloading alarm system was out of order. Finally, the lift was overloaded and dropped from the 11/F to the lift pit.	Injury: 4 persons
29/12/95	Portland Street. Mongkok. Kowloon	When a private car was driving into a public car park lift, the lift moved upward and the car was jammed between the lift floor and the header of the landing.	Injury: 1 person
3/8/93	Shau Kei Wan. H.K.	While the technician was carrying out service to the lift, the hoist ropes suddenly broke and the car cage dropped from the 3/F to the 1/F.	Injury: 4 persons
12/6/93	Hoi Bun Road. Kwun Tong. Kowloon	A cargo lift notified as "suspended service" slipped from the 10/F to the 1/F due to unauthorized use by the persons.	Injury: 4 persons
2/6/93	Java Road. North Point, H.K.	12 construction site workers, travelling in a rack and pinion lift which was specified to carry 8 persons only. The lift fell from the 20/F to the 3/F. It is believed that the cause of the accident was due to overloading.	Death: 12 persons
8/87	Ting Kok Road. Tai Po, N.T.	During lunch time, there were over 55 workers jammed in a passenger/ cargo lift, the lift dropped from the 10/F to the G/F. The cause of the accident is believed to be overloading.	Injury: 55 persons
7/79	Ngau Tau Kok. Kowloon	6 passengers jammed in a rack and pinion lift at a construction site, the lift fell from the 12/F to the G/F.	Death: 6 persons

Table 1: Lift Serious Accidents in Hong Kong

4 ESTABLISHMENT AND IMPLEMENTATION OF A MAINTENANCE STRATEGY

Having considered the elements affecting the design of a maintenance strategy, it is time to establish a unique and sound one. Such strategy can only be established and implemented with the emergence of the following:-

- i. acceptance of the benefits from preventive maintenance
- ii. the establishment of an education and training system
- iii. the establishment of a maintenance system

4.1 Acceptance of the Benefits from Preventive Maintenance

Prevention is much better than diagnosis. In past years, many lift companies would launch their maintenance programmes based on the call-backs from the building management or the users. They believed that such a policy would save a lot of money in the area of maintenance. However, because many accidents are caused by unexpected events, the idea of preventive maintenance has been adopted by most lift companies. The purpose is to prevent serious accidents from occurring where the initial causes are due to minor damage or wear of parts. Preventive maintenance is actually used to delay or prevent the breakdown of equipment and also to reduce the severity of any breakdowns that do occur[7] i.e. to ensure that the lift is still in safe and sound condition after many years of operation. In carrying out good preventive maintenance, several items must be seriously observed and achieved. The lift companies should:-

- i. arrange a good depot distribution network
- ii. provide effective service for the lift repair works
- iii. arrange proper repairs and a regular maintenance inspection[7] programme
- iv. maintain a stock of quality spare parts for replacement works
- v. establish strong maintenance teams, including skilled labour and trained technicians to back up the maintenance works
- vi. supervise the works to ensure that the maintenance teams adhere to the company policy and standards
- vii. analyze the critical parts and past records/breakdown records through regular inspection, replacement or adjustment
- viii. follow the manufacturer's recommendations and standard of parts, so that parts subject to wear should be replaced in advance of deterioration

4.2 The Establishment of an Education and Training System

From the operational point of view, a sound preventive maintenance programme must be supported by a strong maintenance team with strong technical background knowledge. Hence, a comprehensive training system must be provided by the lift company so that the safety[8] which in turn reflects the quality of works, can be sustained. A flowchart showing an education and technical training programme is depicted in Figure 3.

By undertaking such a programme, the maintenance personnel can acquire the necessary knowledge to support their works.

Apart from the training provided to the front line technicians, all functional teams relating to the maintenance works, such as the emergency call team, should receive proper training in order to sustain good quality service and maintenance works.

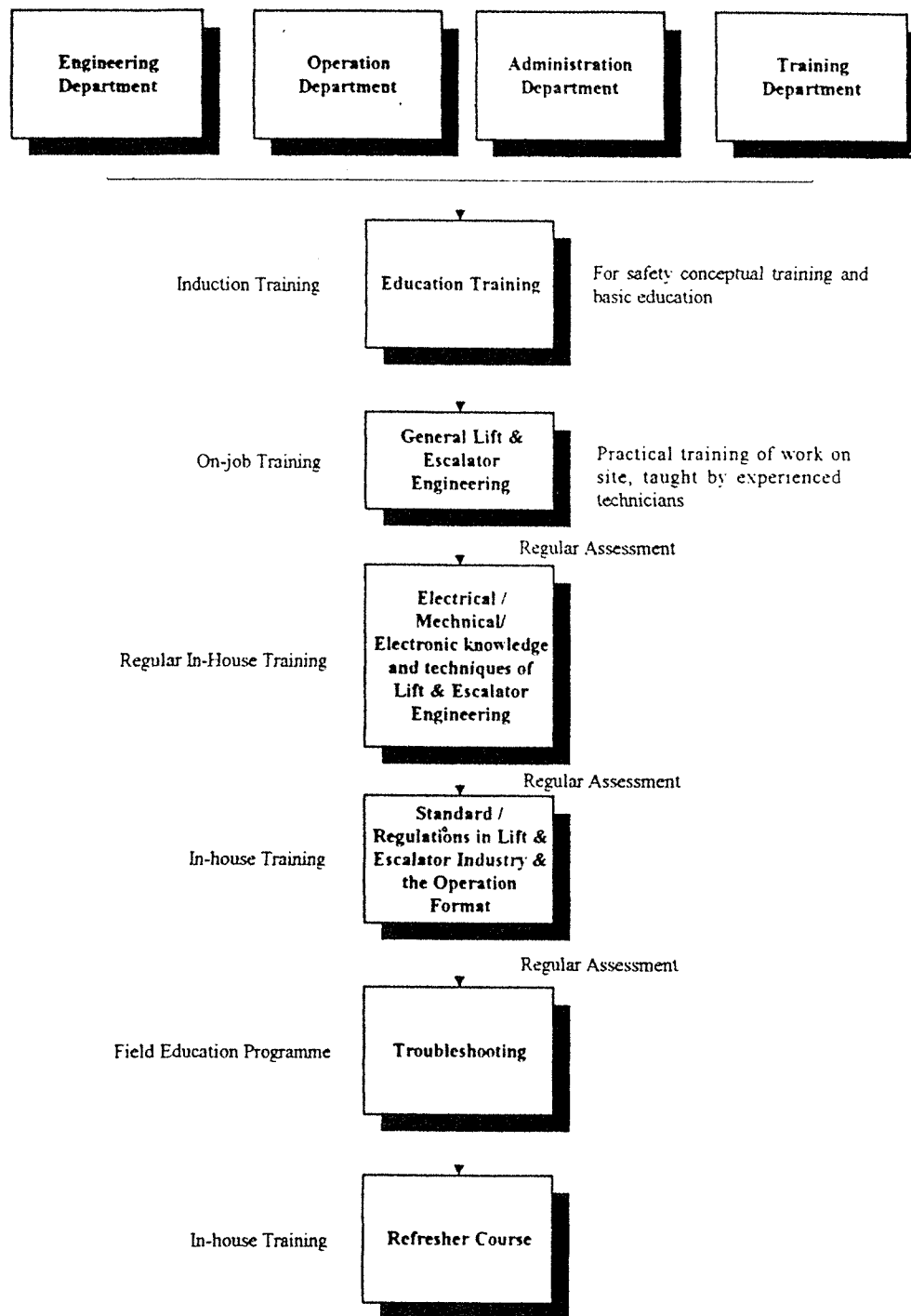


Figure 3: Education & Technical Programme

4.3 The Establishment of a Maintenance System

The lift company should establish a comprehensive system for the maintenance works so that the maintenance strategy can be effectively achieved. The objectives of establishing such a system by management, are to fulfil government requirements, control costs and ensure the quality and safety of operation. Figure 4 summarizes such a system.

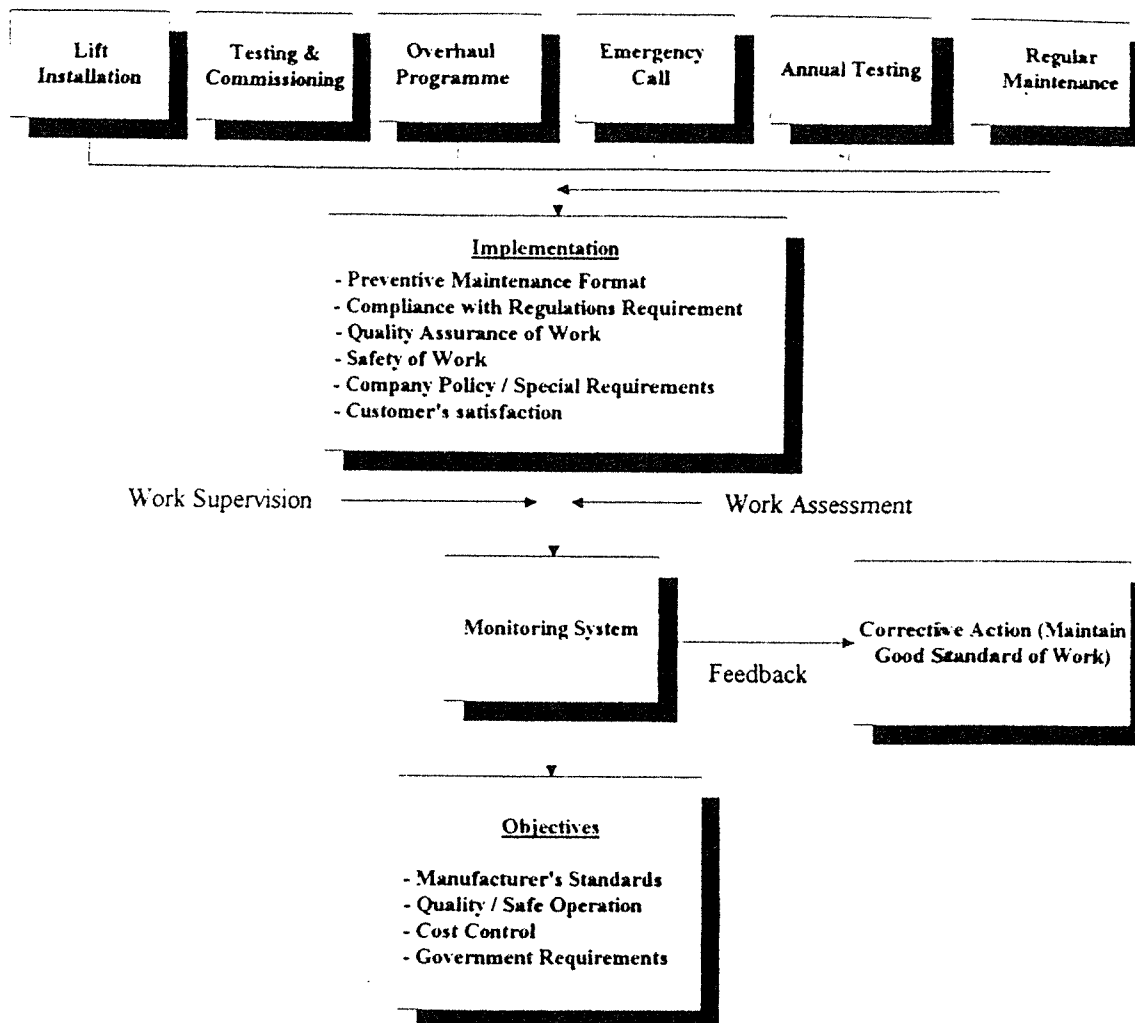


Figure 4: Maintenance System

5 ASSESSMENT OF THE MAINTENANCE STRATEGY

Once the maintenance strategy has been established and implemented, it is necessary to assess whether this strategy is successful. As computer technology is widely applied in different areas especially for decision making, it can be adopted in the lift industry to analyze the performance of the maintenance strategy. An external monitoring system should be introduced in parallel so that a standard and objective assessment can be obtained. In the following, these two respects will be discussed briefly.

5.1 Computer Technology

Computerized Maintenance Management Systems (CMMS) - As the parameters involved in designing the maintenance strategy are dependent variables and very complicated, it would be difficult to study these by traditional decision making methods. Therefore CMMS would be of great help in assisting maintenance decision making. CMMS is a database which stores and collects data. By providing all the necessary information to the system, it will automatically perform data recording and generate relevant data for further analysis.

Software Development for Modelling and Simulation - Having obtained all the required data from CMMS, mathematical models of novel decision situations, based on the data collected, should be built and then followed by the development of PC-based software. By doing so, the data can be analyzed relatively easily and the modelling technique can

be used to provide an optimal solution for maintenance decision making. Different types of mathematical models can be adopted for such purposes. For example, "Weibull Analysis" for component replacement which involves probability and statistics, "Discounted Cash Flow Analysis" for capital equipment replacement. It is important that all data collected and models built are based on reality, with reasonable assumptions which are representative of real situations. Based on these mathematical models, relevant software can be developed for maintenance decision making[9].

Once the solution has been generated, it can be used to compare with the actual results and assess the performance of the maintenance strategy. Correction can then be made if there is any difference between the actual and the computed results.

5.2 Monitoring System

Maintenance Assessment Scoring System (MASS) - It should be noted that if there is a system to monitor the performance of the lift companies, the maintenance programme will be carried out more efficiently and effectively. In Hong Kong, the Housing Authority with the largest portfolio of public housing in the world, is using a new system, the "Maintenance Assessment Scoring System (MASS)", to monitor the performance of various lift companies' performance, based upon statistical data and the findings of periodic inspection. The strength of this system is that subjective judgment by the personnel who carry out the assessment under the conventional system, is practically eliminated. Besides, MASS can also serve as a management tool to identify any weakness of the lift companies that require improvement[10].

In adopting the aspects discussed above, it is believed that the lift company can have a thorough appraisal of its maintenance strategy internally and externally.

6 CONCLUSIONS

Maintenance plays a substantial part in the lift and escalator industry. Before developing the maintenance strategy and the design of a good maintenance programme, the advancement in technology in lift design must be recognized. The life cycle of components or equipment, resource requirements, behaviour of building management and users, quality of maintenance personnel, regulations concerning the lift industry and action taken after the occurrence of an accident must be considered.

The establishment and implementation of the maintenance strategy must be supported by the emergence of the acceptance of the benefits from preventive maintenance, the establishment of an education and training system as well as a maintenance system.

It is noted that assessment should be made to evaluate whether the strategy is successful. Computer technology and an external monitoring system will be helpful to provide a fair assessment in this respect.

In conclusion, a sound maintenance strategy should provide the clients with a safe and reliable lift, thereby minimize the frequency of accidents which will sustain the competitiveness of the company and maximize the reputation and profitability of the company.

7 ACKNOWLEDGMENT

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