CHAPTER 1

INTRODUCTION

1.1 Background Study

From the topic, “A study on Maintainability of Academic Building Elevators”, there are two major components or keywords in the title, “maintainability” and “elevators”.

Maintainability is an inherent characteristic of system or product design. It pertains to the ease, accuracy, safety and economy in the performance of maintenance actions. A system should be designed such that it can be maintained without large investments of time, at the least cost, with a minimum expenditure of resources (personnel, materials, facilities and test equipment). One goal is to maintain a system effectively and efficiently in its intended environment, without adversely affecting the mission of the system.

Maintainability is the “ability” of an item to be maintained, whereas maintenance constitutes a series of actions necessary to restore or retain an item in an effective operational state. Maintainability is a design parameter whereas maintenance is required as a consequence of design.

Maintainability is not to be confused with reliability which is often associated together and go hand-in-hand. According to Smith (2001), Reliability is defined as *The probability that an item will perform a required function, under stated conditions, for a* *stated period of time. Reliability is therefore the extension of quality into the time domain and may be paraphrased as 'the probability of repair in a given time'* whereas Maintainability is defined as *The probability that a failed item will be restored to operational effectiveness within a given period of time when the repair action is performed in accordance with prescribed procedures. This in turn can be paraphrased as 'The probability of repair in a given time'.*

Maintainability, as a characteristic of design, can be expressed in terms of maintenance frequency factors, maintenance times and labour-hour factors and maintenance cost. More specifically, maintainability can be defined as:

I. A characteristic of design installation which is expressed as the probability that an item will be retained in or restored to a specified condition within a given period of time, when maintenance is performed in accordance with prescribed procedures and resources.

II. A characteristic of design installation which is expressed as the probability that maintenance will not be required more than *x* times in a given period, when the system is operated in accordance with prescribed procedures by personnel with the proper skills. This may be analogous to reliability when the latter deals with the overall frequency of maintenance.

III. A characteristic of design and installation which is expressed as the probability that the maintenance cost for a system or product will not exceed *y* Ringgit per designated period of time, when the system is operated and maintained in accordance with prescribed procedures. Cost must address such factors such as resource consumption and environmental impacts as well as their Ringgit equivalents.

An elevator or elevator is a vertical transport vehicle that efficiently moves people or goods between floors of a building. They are generally powered by electric motors that either drive traction cables and counterweight systems, or pump hydraulic fluid to raise a cylindrical piston. Elevators began as simple rope or chain hoists. An elevator is essentially a platform that is either pulled or pushed up by a mechanical means. A modern day elevator consists of a cab (also called a "cage" or "car") mounted on a platform within an enclosed space called a shaft or sometimes a "hoistway". In the past, elevator drive mechanisms were powered by steam and water hydraulic pistons. In a "traction" elevator, cars are pulled up by means of rolling steel ropes over a deeply grooved pulley, commonly called a sheave in the industry. The weight of the car is balanced with a counterweight. Sometimes two elevators always move synchronously in opposite directions, and they are each other's counterweight. The friction between the ropes and the pulley furnishes the traction which gives this type of elevator its name.

The UTP academic building elevators are manufactured and serviced by Schindler Elevators Corporation and Antah Schindler Sdn Bhd respectively. Antah Schindler Sdn Bhd is a member of the Jardine Schindler Group.

Schindler Holdings is the largest escalator manufacturer and the 2nd largest elevator manufacturers in the world behind Otis Elevator Company. Schindler was founded in 1874, in Lucerne, Switzerland. Their current headquarters is located in Hergiswil, Switzerland. At the moment, they have operations is more than 100 companies over 6 continents. Their estimated revenues are in the region of USD 9 billion (at end of 2006).

Jardine Schindler Group (JSG) is a Joint Venture between Jardine Matheson in Hong Kong and Schindler Group of Switzerland, who between them bring over 300 years of experience in business management, regional specialization and engineering excellence.

JSG is headquartered in Hong Kong and designs, engineers, installs, maintains and modernizes elevators, escalators and moving walkways in Brunei, Cambodia, Hong Kong, Malaysia, Indonesia, the Philippines, Singapore, Thailand, Taiwan and Vietnam.
JSG employs some 3,000 staff in a variety of specialist disciplines, ranging from engineering design to construction management. The business is split into two principle operating divisions: New Installations, focusing on new construction projects, and Existing Installations, providing maintenance and modernization services.

On average, 100 million people throughout the Asia Pacific regions will be transported by equipment supplied and maintained by JSG on any given day.

1.2 Problem Statement

Elevators are considered an essential facility in any building. UTP academic building elevators do not frequently experience breakdowns (once in two/three months) but when they do, it would cause a lot of hassle and the time interval to repair them would take roughly two to three hours. This would turn out to be a hassle for all the users which include lecturers, students and visitors especially when they are out of service causing the users to make the unnecessary detour. It would be more troublesome for the users if they were in a rush to chase a dateline or an appointment. Worst case scenario would be if the elevator breaks down with people in it. So in this case, we can say prevention is better than cure. To prevent this problem from occurring in the future, we must improve the system by enhancing its reliability and maintainability. Maintainability should be considered during the design stage. Now the problem is that the elevators are already in operation and then we would want to enhance the maintainability of the elevators.

1.3 Objective

The main objective of this project is to analyse the maintainability of the existing academic building elevators in the UTP campus and finds ways to enhance the maintainability of the elevator.

CHAPTER 2

LITERATURE REVIEW

All the elevators in UTP are manufactured and serviced by Schindler and Antah Schindler Sdn Bhd respectively. Basically there are 3 types of elevators used in UTP which are the Machine Room-Less elevators, Hydraulic elevators and Electric Elevators. The ones used in the academic blocks are all the Electric Traction Elevator type.

2.1 Electric Traction Elevators

Another type of elevator used is the Electric Traction type elevators. One of Schindler's models using the Electric Traction system is the Schindler 400A Electrical Traction Elevator. The Schindler 400A Traction Elevator System combines exceptional performance with valuable space, time and energy savings. Designed for general-purpose passenger use or hospital and service applications, the Schindler 400A Traction Elevator is specified for low- or mid-rise buildings and can incorporate up to 20 stops and travel up to a maximum of 200' (61 m). The small footprint of the gearless Schindler 400A elevator reduces the amount of vertical and horizontal building space required, and the streamlined hoistway allows for simpler site preparation and faster installation. Compact and environmentally friendly, the 400A consumes 30% less energy than traditional geared models without sacrificing the smooth, quiet operation and reliability for which Schindler products are known. The Schindler 400A is available in machine room-less, machine room side and machine room above configurations.

2.1.1 Sub-Types of Electric Traction Elevators

Machine Room-Less (MRL)

A small closet-sized space requiring no roof penetration can replace a conventional machine room. The control space will house a compact controller cabinet and can be located on the top floor adjacent to any hoistway-wall. All elevator machinery equipment is located in the hoistway overhead and is accessible from the car top

Machine Room Side (MRS)

A mini-machine room can be located alongside the hoistway on the top floor to house the controller cabinet and provide access to the governor when necessary. All elevator machinery equipment is located in the hoistway overhead and is accessible from the car top.

Machine Room Above (MRA)

A conventional machine room containing all the elevator machinery equipment with a footprint no bigger than the hoistway itself can be located on the roof directly over the hoistway. Equipment mounting can be accomplished using a traditional structural concrete slab. Rail mounting is also available with some applications.

Benefits

- Small space-saving footprint
- Little to no roof penetration required for MRL/MRS®
- 30% more efficient than traditional geared models
- Self-diagnostic, on-board sensors
- Eco-friendly clean, quiet operation
- Available in a variety of design configurations to match most decors and site requirements
- Available capacities of 2100-4500 lb (953- 2041 kg) to suit a wide range of applications
- E-access to online tools for real-time project information

- Smooth, quiet, reliable performance
- Hassle-free design assistance and start-to-finish customer support

Components Standard 400A elevator components include the following:

- Hoistway mechanicals such as guide rails, rail brackets, buffers and machinery supports
- Car structure that supports the cab and safety device
- UL fire-rated entrance assemblies including doors, jambs, sills and hardware
- Counterweightframe with steel filler weights
- Cab with steel shell walls and top ceiling
- Cab with exhaust fan and handrails
- Cab fixtures, including the main car operating panel, pushbuttons, main lighting, emergency lighting, fire-fighter's services, switches and accessories
- "Permanent magnet" motor, variable frequency AC drive, governor and safety device
- Overload sensors
- Phase protection
- UL, CSA or CUL approved Miconic GX microprocessor controller, controls, pushbuttons and wiring
- Integral jamb-mounted hall fixtures, to include up and down buttons and fixture cover platesQKS16 VF door operator
- Braille and audible signals
- ADA compliant telephone
- Infrared Light Curtain door protection
- Load weighing device
- Locking service panel in car operating panel
- Car lanterns
- Digital car position indicator
- Schindler Remote Monitoring

2.1.2 Electric Traction Elevator Configuration

Figure 2.1: The Schindler 400A MRL System

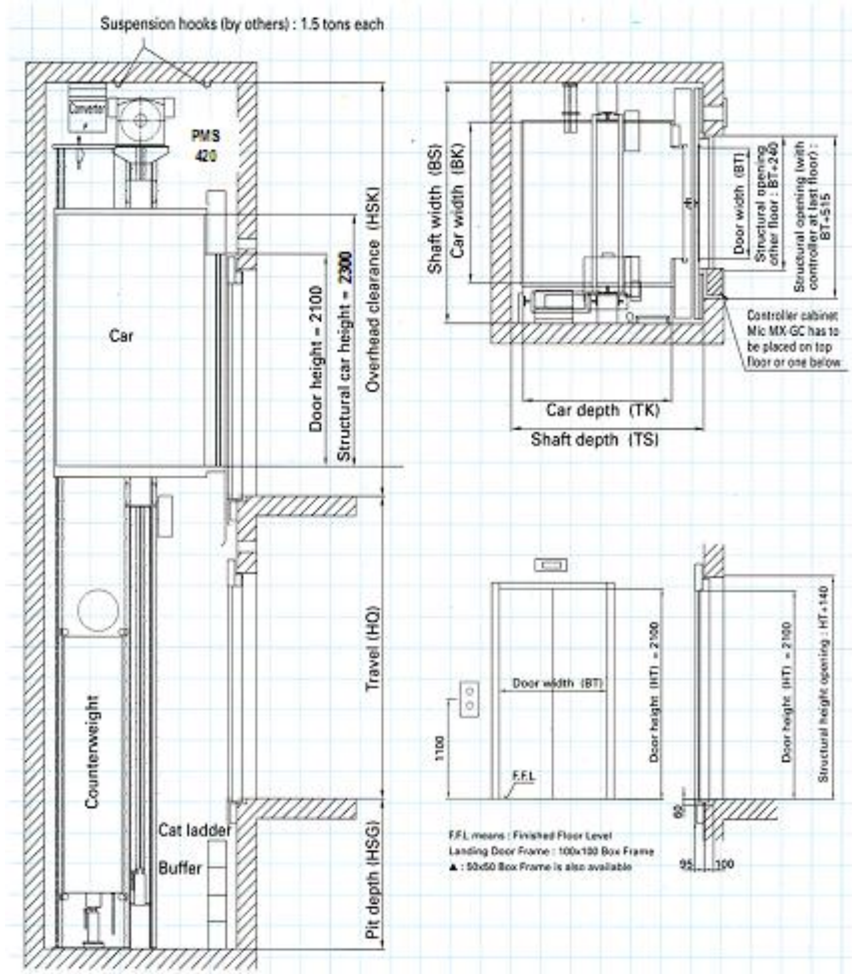

Figure 2.2 Layout of the Schindler 400A System

2.1.3 Electric Traction Elevator Components

 *Figure 2.3: Permanent Magnet Gearless Drive*	**Permanent Magnet Gearless Drive** ▪ Eco-friendly, **oil-free operation** ▪ Compact dimensions, with optimal shaft layout to free up building space ▪ Low weight and noise for maximum freedom in positioning the elevator ▪ **Internal expanding double circuit brake for protecting against elevator car speeding**, as required by EN81 ▪ Up to 40% energy saving compared to conventional geared machines, benefiting both the environment and operating budget.
 *Figure 2.4: MX-GC Controller*	**MX-GC Controller** ▪ “Cost of service” controllers, universally acknowledged to be the best-performing elevator management system in the market ▪ Wide range of supported peripheral components, control functions & features ▪ Integrated with revolutionary “Miconic 10” destination hall call control system ▪ **Computer aided field tools to reduce lead times for commissioning and troubleshooting** ▪ Latest SIM card technology to allow easy and quick upgrading and configuration.
 *Figure 2.5: WVF Varidor 30 Door System*	**WVF Varidor 30 Door System** ▪ Smooth, quiet and reliable door operation achieved through variable speed acceleration ▪ Simple and modular mechanical design for easy installation ▪ **High reliability through a simple design with low number of parts** ▪ The fast starting clutch saves up to 1.5 seconds every time the door opens or closes, effectively reducing floor-to-floor time.

2.2 Time & Frequency Standards

Based on the journal by Nayanthara de Silva, Mohammed F. Dulaimi, Florence Y.Y. Ling, George Ofori, of the National University of Singapore entitled "Improving the maintainability of buildings in Singapore", there are a few time & frequency standards which were identified. They are;

- ☐ Mean Down Time (MDT)
- ☐ Mean Time To Repair (MTTR)
- ☐ Mean Response Time (MRT)
- ☐ Mean Time Between Failure (MTBF)
- ☐ Mean Time Between Maintenance (MTBM)
- ☐ Availability

Chapter 3

METHODOLOGY

Throughout this project, there are various tools of analysis which are required to obtain and narrow down the cause of the problems and to improve maintainability. Among them are:

3.1 Root Cause Analysis (RCA)

Root cause analysis (RCA) is a class of problem solving methods aimed at identifying the root causes of problems or events. The practice of RCA is predicated on the belief that problems are best solved by attempting to correct or eliminate root causes, as opposed to merely addressing the immediately obvious symptoms. By directing corrective measures at root causes, it is hoped that the likelihood of problem recurrence will be minimized. However, it is recognized that complete prevention of recurrence by a single intervention is not always possible. Thus, RCA is often considered to be an iterative process, and is frequently viewed as a tool of continuous improvement.

RCA initially is a reactive method of problem detection and solving. This means that the analysis is done after an event has occurred. By gaining expertise in RCA it becomes a pro-active method. This means that RCA is able to forecast the possibility of an event even before it could occur.

In this case, the most suitable type of RCA is the Failure-based RCA which is rooted in the practice of failure analysis as employed in engineering and maintenance.

Basic Methodology for RCA;

1. Define the problem.
2. Gather data/evidence.
3. Ask why and identify the causal relationships associated with the defined problem.
4. Identify which causes if removed or changed will prevent recurrence.
5. Identify effective solutions that prevent recurrence, are within your control, meet your goals and objectives and do not cause other problems.
6. Implement the recommendations.
7. Observe the recommended solutions to ensure effectiveness.

3.2 Analysis of Design for Maintainability Factors

Key Design Areas

a) Accessibility

- ✓ Low-reliability parts should be the most accessible and must be easily removed with the minimum of disturbance. There must be enough room to withdraw such devices without damaging other parts.

b) Adjustability

- ✓ The amount of adjustments required during normal system operation can be minimized by generous tolerance in the design, aimed at low sensitivity and drift. It is usually necessary for adjustments and alignments to be carried out in a sequence and this must be specified in the maintenance instructions. The designer should understand that where drift in a particular component can be compensated for by the adjustment of some other item then, if that adjustment is difficult or critical, the service engineer will often change the drifting item, regardless of its cost.

3.3 Time & Motion Study

There are two key elements in Time & Motion Study which are time and motion respectively. For the "Motion" aspect of this study, analysis and record what is carried out during maintenance, where each and every step of the maintenance procedure is recorded. And as for the "Time" aspect of this study, analysis of how long the duration of each step of the maintenance procedure is done.

As part of the Time & Motion Study, it was done at Academic Block 15 & 17 elevators. Both these elevators are Electrical Traction Elevators where the Motor Room is located beneath the elevator shaft.

3.4 Data Gathering and Analysis

- Obtained Maintenance Records for Academic Building Elevators (Block 1-5, 13-23)
- Maintenance Records were done monthly for every month in 2009
- Data Gathered
  - Accumulated Breakdown Of Elevators 2009
  - Detailed Summary of Breakdown 2009
  - Intercom Inspection Report

- Analysis Done
  - Mean Down Time (MDT)
  - Mean Time To Repair (MTTR)
  - Mean Response Time (MRT)
  - Mean Time Between Failure (MTBF)
  - Mean Time Between Maintenance (MTBM)
  - Availability

3.4.1 Time & Frequency Standards

The following are measurements that can be used for maintainability and maintenance. They should be establish on programs as part of the initial objectives and goals, and then finalized as specifications.

3.4.1.1 Mean Down Time (MDT)

MDT measures the average duration the equipment cannot be used. Downtime starts when it is detected by the user, which may be at a later time than when the failure actually occurred. Mathematically, it is given by:

$$MDT = \frac{\Sigma\, Down\ Time}{\text{No Of Failures}}$$

3.4.1.2 Mean Time To Repair (MTTR)

MTTR is the average time it takes to fix the equipment once the technician has gained access to it. It includes troubleshooting and fault-isolation, remove/repair/replace, and checkout.

Mathematically, it is given by:

$$MTTR = \frac{\Sigma\, Repair\ Time}{\text{No Of Failures}}$$

3.4.1.3 Mean Response Time (MRT)

Response Time is defined as the time duration from the receipt of the request for maintenance until the job starts. Mathematically, it is given by:

$$MRT = \frac{\Sigma\, Response\ Time}{\text{No Of Failures}}$$

3.4.1.4 Mean Time Between Failure (MTBF)

Mean time between failures (MTBF) is the predicted elapsed time between inherent failures of a system during operation. MTBF can be calculated as the arithmetic mean (average) time between failures of a system.

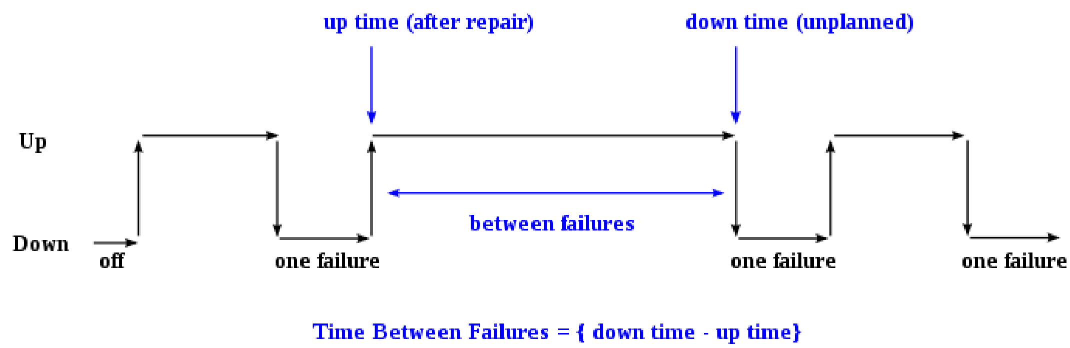

Figure 3.1: Time Between Failure

Referring to the figure above, the MTBF is the sum of the operational periods divided by the number of observed failures. Mathematically, it is given by:

$$MTBF = \frac{\Sigma\,(Down\,Time - Up\,Time)}{\text{No Of Failures}}$$

3.4.1.5 Mean Time Between Maintenance (MTBM)

MTBM is defined as the average time duration between each occurrence of maintenance works, albeit Preventive Maintenance (PM) and Corrective Maintenance (CM) works. Mathematically, it is given by:

$$MTBM = \frac{Total\,Time}{Number\ of\ CM\ \&\ PM\ Occurrences}$$

3.4.1.6 Availability

Availability is defined as:

1. The degree to which a system, subsystem, or equipment is operable and in a committable state
2. The proportion of time a system is in a functioning condition
3. The ratio of (a) the total time a functional unit is capable of being used during a given interval to (b) the length of the interval.

There are three types of availability:

1. Operational Availability (A_o)
2. Inherent Availability (A_i)
3. Achieved Availability (A_a)

Operational Availability

Operational availability (A_o) is a measure of the average availability over a period of time. A_o considers all experienced sources of downtime, which includes both Preventive Maintenance & Corrective Maintenance, and all administrative downtime, materials, and logistic downtime. Operational availability is the ratio of the system uptime and total time.

In lay man's term, A_o measures the total amount of time the equipment does its job when called upon. Mathematically, it is given by:

$$Ao = \frac{Uptime}{Operating\ Cycle}$$

Inherent Availability

Inherent availability (A_i) is the steady state availability when considering only the corrective downtime of the system. A_i is the designer's best possible situation. It is unencumbered by PM, environmental concerns, or any delay. Mathematically, it is given by:

$$Ai = \frac{MTBF}{MTBF + MTTR}$$

Achieved Availability

Achieved availability (A_a) is very similar to inherent availability with the exception that preventive maintenance (PM) downtimes are also included. Specifically, it is the steady state availability when considering corrective and preventive downtime of the system. It can be computed by looking at the mean time between maintenance actions, MTBM and the mean maintenance downtime. Mathematically, it is given by:

$$Aa = \frac{MTBM}{MTBM + MDT}$$

3.5 Process Flow

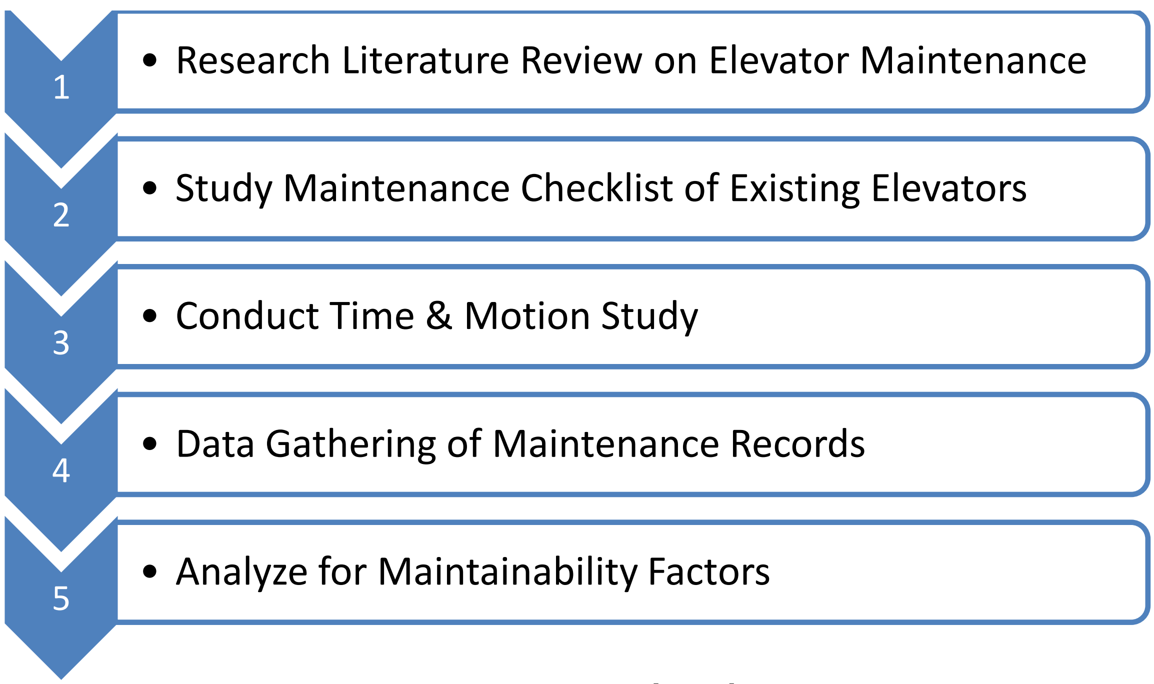

Figure 3.2: Process Flow Chart

Chapter 4

RESULT

Based on the Preventive Maintenance Checklist that has been obtained from the Maintenance Department, we can determine what works are being done during maintenance works. After that, the next step completed is following the Maintenance Department on their next maintenance work on the elevators so that the maintenance works being done can be observed and also the Time & Motion Analysis can be done. The elevator that is used in this research is the elevator in Block 15 and 17. All the academic building blocks are using the same type which is the Electrical Traction Elevators where the Motor Room is located below the elevator shaft. During the observation, the timing on how long it takes to complete each item on the checklist and also the total duration of the repair/maintenance was taken.

The maintenance work or more of an inspection is carried out based on the Preventive Maintenance (PM) Checklist. The PM works of the elevator in the academic blocks can be divided into 4 main areas; Motor Room, Car/Landing, Car Top/ Shaft and Car Bottom/ Pit.

4.1 Time & Motion Study

Check	Work Done	Time taken (minutes)
Motor Room		
General Check	Check motor room lighting, ventilation & cleanliness	2.4
	Ensure schematic diagrams. notices complete and legible	1.5
Check Gearbox	Check oil level & leaks	2.1
Check Sheaves & Pulleys	Lubricate machine devertor pulley if applicable	2.6
	Check Condition of grooves	2.4
Check Controller	Check function of recall control switch operation	1.4
	Ensure the controller cabinets are closed	0.2
	Check main/control fuse	1
Check Overspeed Governor	Check for abnormal noise & vibration	1
Check ARD	Check Battery voltage/ condition. Top up water (if needed)	1.5
	Check function & proper levelling/door opening status	1.6
Total		17.7
Car/Landing		
Check Ropes	Check condition of anti-twist ropes	2
Check Car Fixture	Check for abnormal noise, levelling & comfort	2.1
	Check Alarm Bell & Intercom	1
	Check buttons, indicators/message display if applicable	0.5
Check Car Door	Service/check condition of suspension roller & track	3
	Service door sill and sliding shoes, check clearance	3.5
	Service car door contact/ check tension	3.4
	Check function of car door safety system	3.4
	Check door motor and tension of V-Belt	2.9
	Check function of door holding coil	2.8

Check Landing Door	Service Landing Door contact / check tension	3.1
	Service suspension rollers & track	3.4
	Service landing sill & shoes, ensure proper clearance	3.5
	Check allignment of cam rollers	2.4
	Service landing door self closing device	1.3
Check Landing Fixtures	Check indicators/gongs/buttons	0.2
	Check breaking of Fireman glass & switch	0.1
Total		38.6
Car Top / Shaft		
Check Car Top Equipment	Check cleanliness of car top	1.5
	Check function of Inspection Control swiches & lighting	1.2
Check Car Guide Shoes/Rollers	Check Oil level & flow of automatic lubrications	2.1
Check Shaft Equipment	Check abnormal noise in shaft	1.2
Check CWT Guide Shoes/ Rollers	Check oil level and oil flow of automatic lubricators	1.6
Total		7.6
Car Bottom / Pit		
Check Car Bottom Equipment	Check free movement of safety gears jaw / rollers	2.5
Check Pit Equipment	Check function of stop switch	2.1
	Check pit cleanliness and lighting	2.3
	Check clearance of governor pulley	3.4
Total		10.3
Grand Total		74.2

Table 4.1: Time & Motion Study

4.2 Analysis of Maintenance Records

Based on the Preventive Maintenance records of the elevators for 2009 that has been gathered from the Maintenance Department, the raw data is tabulated to see the trend of elevator breakdowns for the academic blocks which covers block 1-5 and block 13-23. The total number of elevators is 16 elevators.

Elevator No	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Block 1										1			1
Block 2													0
Block 3													0
Block 4													0
Block 5													0
Block 13									1				1
Block 14										1			1
Block 15						1							1
Block 16	1			1									2
Block 17				1	1								2
Block 18													0
Block 19									1				1
Block 20					1								1
Block 21							1				1		2
Block 22							1						1
Block 23	1			1				2			1		5
Total	2	0	0	3	2	1	2	2	2	2	2	0	**18**

Table 4.2: Overall Summary of breakdowns For Academic Block Elevators for 2009

Month	Date	Elevator No.	Mantrap	Time Occurred	Time Attended	Time Completed	Technician	Remarks of Breakdown
Jan	21/1/2009	Block 16	1	14:33	14:45	17:40	Sukri	KNR-O Faulty. Replaced KNR-O
	23/1/2009	Block 23	1	14:01	14:13	18:20	Zakuan	Car Door Cam open. Replaced Lust Inverter
Feb	No Breakdowns							
March	No Breakdowns							
April	3/4/2009	Block 17	0	14:37	14:58	18:50	Zakuan	KNR-O PHS Sensor Faulty. Replaced KNR-O Sensor
	10/4/2009	Block 23	0	8:13	8:30	12:00	Zakuan	AS Panel VFVE Fan Faulty. Replaced VFVE Fan
	16/4/2009	Block 16	0	9:03	9:15	14:20	Zakuan & Sukri	KUET Fault. PHUET Sensor Faulty. Replaced PHUET Sensor
May	6/5/2009	Block 17	1	7:12	7:30	10:05	Zakuan	PHUET Faulty. Replaced PHUET
	15/5/2009	Block 20	1	7:45	8:02	10:00	Zakuan	RKPH Relay Faulty. Replaced RKPH Relay.
June	24/6/2009	Block 15	0	14:03	14:19	16:14	Zakuan	Error RSK Fault. Replaced SKE Print
July	9/7/2009	Block 22	0	8:53	9:06	11:00	Zakuan	KNR-O Faulty. Replaced KNR-O
	16/7/2009	Block 21	0	8:20	8:34	10:30	Zakuan	PHUET Faulty. Replaced PHUET
Aug	11/8/2009	Block 23	0	11:39	11:52	17:50	Sukri	PHS KNR-O Faulty. Replaced KNR-O Sensor
	27/8/2009	Block 23	0	15:17	15:30	17:30	Sukri	KNR-O PHS Sensor Faulty. Replaced KNR-O Sensor
Sept	4/9/2009	Block 13	0	16:21	16:35	19:20	Zakuan	KNR-O PHS Sensor Faulty. Replaced KNR-O Sensor
	28/9/2009	Block 19	0	8:20	8:36	16:00	Sukri	ASILOG Print Faulty. Replaced ASILOG Print
Oct	19/10/2009	Block 1	0	9:36	9:43	11:00	Zakuan	MBB Print Faulty. Replaced MBB Print
	20/10/2009	Block 14	0	10:05	10:14	14:00	Zakuan	Lust Inverter Faulty. Replaced Lust Inverter
Nov	6/11/2009	Block 21	0	8:21	8:35	11:30	Zakuan	MBB Print Faulty. Replaced MBB Print
	25/11/2009	Block 23	0	8:40	8:57	17:36	Zakuan & Sukri	Proguard Faulty. Replaced with Minimax
Dec	No Breakdowns							

Table 4.3: Detailed Breakdown Summary Of Academic Block Elevators for 2009

4.2.3 Calculations

From the data gathered regarding each breakdown, the repair time, down time, response time and time between failures are calculated.

- Repair Time is Time Completed – Time Attended.
- Down Time is Time Completed – Time Occurred.
- Response Time is Time Attended – Time Occurred.
- Time between Failures is Occurrence of $Failure_{n+1}$-$Failure_{n}$.

Month	Date	Elevator No.	Mantrap	Time Occurred	Time Attended	Time Completed	Repair Time (Mins)	Downtime (Mins)	Response Time (Mins)	Time Between Failures (Mins)
Jan	21/1/2009	Block 16	1	14:33	14:45	17:40	175	187	12	0
	23/1/2009	Block 23	1	14:01	14:13	18:20	247	253	12	2661
Feb	No Breakdowns									
March	No Breakdowns									
April	3/4/2009	Block 17	0	14:37	14:58	18:50	232	253	21	99137
	10/4/2009	Block 23	0	8:13	8:30	12:00	210	227	17	9443
	16/4/2009	Block 16	0	9:03	9:15	14:20	305	317	12	8463
May	6/5/2009	Block 17	1	7:12	7:30	10:05	155	173	18	26932
	15/5/2009	Block 20	1	7:45	8:02	10:00	118	135	17	12820
June	24/6/2009	Block 15	0	14:03	14:19	16:14	115	131	16	57843
July	9/7/2009	Block 22	0	8:53	9:06	11:00	114	127	13	19719
	16/7/2009	Block 21	0	8:20	8:34	10:30	116	130	14	9920
Aug	11/8/2009	Block 23	0	11:39	11:52	17:50	358	371	13	36069
	27/8/2009	Block 23	0	15:17	15:30	17:30	120	133	13	22887
Sept	4/9/2009	Block 13	0	16:21	16:35	19:20	165	179	14	11451
	28/9/2009	Block 19	0	8:20	8:36	16:00	374	460	16	33900
Oct	19/10/2009	Block 1	0	9:36	9:43	11:00	77	84	7	29856
	20/10/2009	Block 14	0	10:05	10:14	14:00	226	235	9	1385
Nov	6/11/2009	Block 21	0	8:21	8:35	11:30	175	189	14	22701
	25/11/2009	Block 23	0	8:40	8:57	17:36	519	536	17	27190
Dec	No Breakdowns									

Table 4.4: Detailed Breakdown Summary Of Academic Block Elevators for 2009 including calculated Time Factors

Mean Down Time (MDT)

$$MDT = \frac{\Sigma\, Down\ Time}{\text{No Of Failures}}$$

$MDT = \frac{4120\ mins}{\text{18 Failures}}$ = **228.889 min**

For 2009, the MDT is **229 min.**

Mean Time To Repair (MTTR)

$$MTTR = \frac{\Sigma\, Repair\ Time}{\text{No Of Failures}}$$

$MTTR = \frac{3801\ mins}{\text{18 Failures}}$ = **211.1667min**

For 2009, the MTTR is **211 min.**

Mean Response Time (MRT)

$$MRT = \frac{\Sigma\, Response\ Time}{\text{No Of Failures}}$$

$MRT = \frac{255\ mins}{\text{18 Failures}}$ = **14.1667 min**

For 2009, the MRT is **14 min.**

Mean Time Between Failure (MTBF)

$$MTBF = \frac{\Sigma\ (Down\ Time - Up\ Time)}{\text{No Of Failures}}$$

To calculate the MTBF, firstly the Total Summation of (downtime-uptime) is calculated.

∑(Downtime-uptime)

=2661+99137+9443+8463+26932+12820+57843+19719+9920+36069+22887+ 11451+33900+29856+1385+22701+27190

= **432377 min**

For 2009, the total number of failures of elevators is 18 failures.

So, the MTBF for 2009 can be calculated as:

$MTBF = \frac{432377\ mins}{\text{18 Failures}}$= **24020 min**

For 2009, the MTBF is **24020 min**

Mean Time Between Maintenance (MTBM)

$$MTBM = \frac{Total\ Time}{Number\ of\ CM\ \&\ PM\ Occurrences}$$

PM works are carried out once a month for each elevator. In total, there are 16 academic building elevators.

No. of Preventive Maintenance (PM) Occurrences	16 elevators x 1/month x 12 months = **192**
No. of Corrective Maintenance (CM) Occurrences	**18**
Total of CM & PM occurrences	192 + 18 = **210**
Total Time (year 2009 in minutes)	**525600 mins**

Table 4.5: MTBM Calculations

Based on the data collected above, the MTBM can be calculated:

$MTBM = \frac{525600\ mins}{210\ occurrences}$= **2502.857 mins**

Availability

Operational Availability

$$Ao = \frac{Uptime}{Operating\ Cycle}$$

$$Ao = \frac{Uptime}{Operating\ Cycle} = \frac{432377\text{mins}}{365\text{ days}} = \mathbf{0.8226}$$

Inherent Availability

$$Ai = \frac{MTBF}{MTBF + MTTR}$$

$$Ai = \frac{MTBF}{MTBF+MTTR} = \frac{24020\text{ min}}{24020+211\text{ min}} = \mathbf{0.9912}$$

Achieved Availability

$$Aa = \frac{MTBM}{MTBM + MDT}$$

$$Aa = \frac{MTBM}{MTBM+MDT} = \frac{2502.857\text{ mins}}{2502.857+229\text{ mins}} = \mathbf{0.916}$$

CHAPTER 5

DISCUSSION

5.1 Breakdowns Analysis

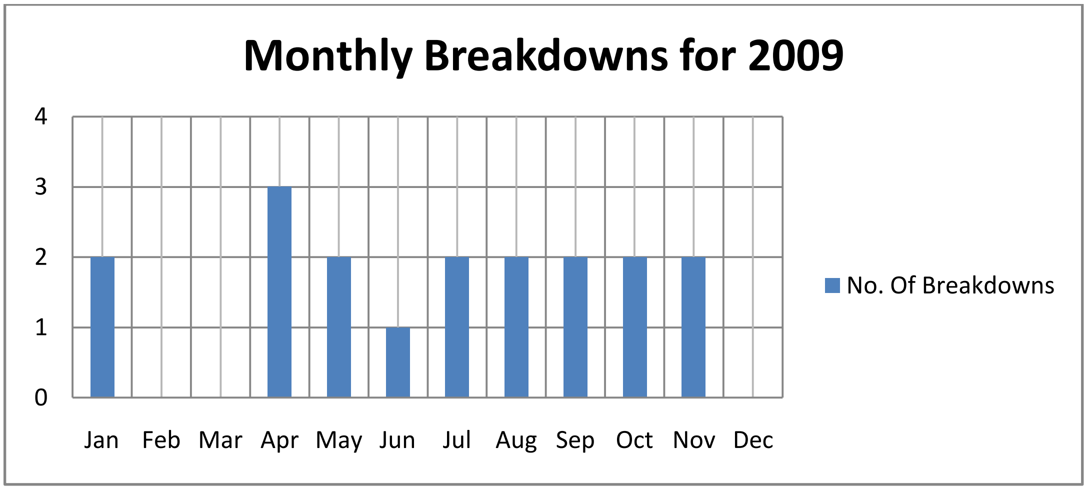

Chart 5.1: No of Monthly Breakdowns for 2009

Based on the chart above, we can see that the total number of breakdowns for 2009 is 18 breakdowns, meaning that the average breakdown per month is 1.5.

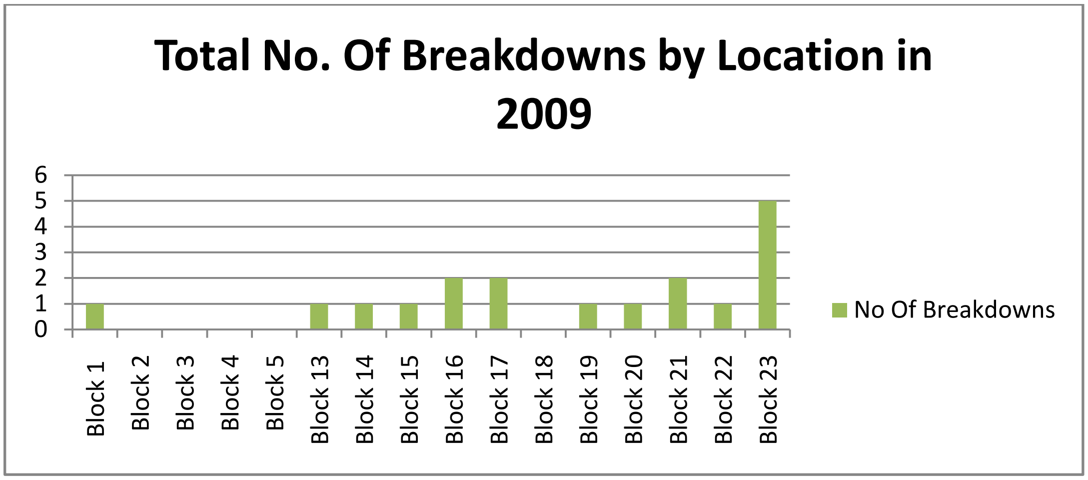

Chart 5.2: Total No of Breakdowns By Location in 2009

Based on the chart showing breakdowns based on the location of the elevator, we can find that the most frequent elevator breakdowns happens at Academic Block 23 with 5 breakdowns. This may be due to the heavier usage of the elevators in this block compared to other blocks.

5.2 Intercom System Failure Analysis

From the data gathered from the maintenance department, after receiving complaints regarding the Intercom System, they started to do fortnightly checks on the Intercom System starting from February 2009. Based on the Chart 5.3, we can see the trend that in the beginning of the year, as soon as just these checks were implemented, there were a lot of problems with the intercom system, meaning that they were in bad shape. After 5 months of the Intercom System checks, the problems started to decrease and from June to November, there were only 2 problems with the Intercom System. The problem started again in December where the number of problems shot up from zero to eight cases. This may be due to the fact of wear and tear plus the factor of December being the rainy season whereby some of the electronic components may be affected.

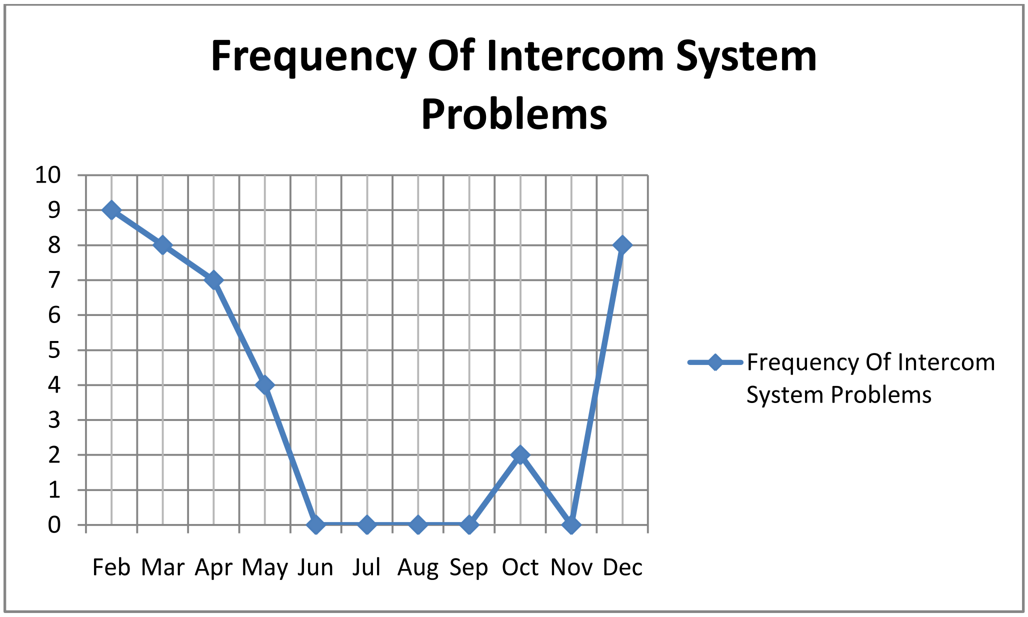

Chart 5.3: Frequency Of Intercom System Problems 2009

5.3 Frequent Component Breakdowns

During the maintenance works, the Antah Schindler Technician who was in charge of the Preventive Maintenance works is MR Zakuan. He said that the overall maintainability and reliability of the elevators in UTP is far better to those elevators elsewhere.

Reason of Breakdown	Frequency
KNR-O PHS Sensor Faulty	6
Lust Inverter Faulty	2
AS Panel VFVE Fan Faulty	1
PHUET Sensor Faulty	3
RKPH Relay Faulty	1
SKE Print Faulty	1
ASILOG Print Faulty	1
MBB Print Faulty	2
Proguard Faulty	1
Total	18

Table 5.1: Reasons Of Breakdowns

5.3.1 KNR-O PHS Sensor

- Leveling Sensor – Detects whether floors are level with carriage

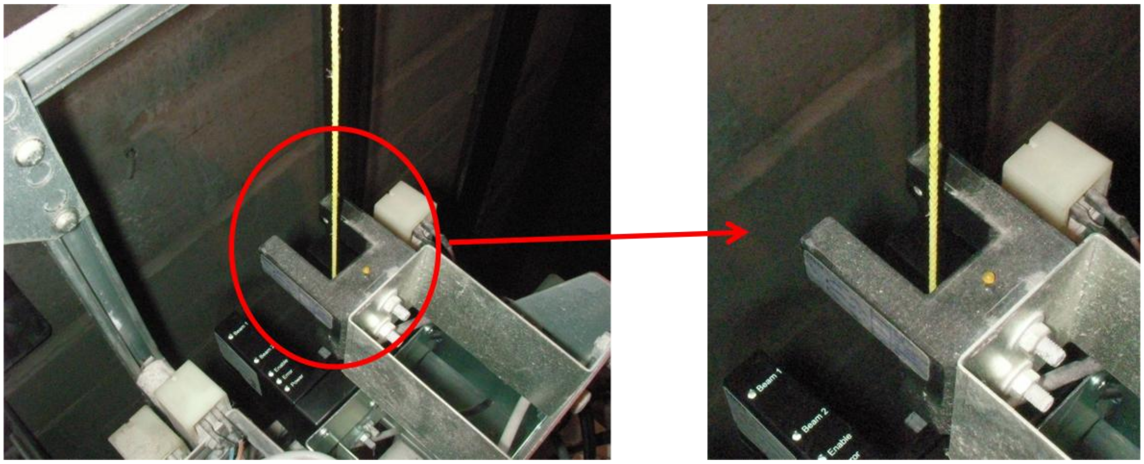

Figure 5.1: KNR-O PHS Sensor

5.3.2 PHUET Sensor

- Gives signal that the elevator carriage and floors are level
- Only then the door will open

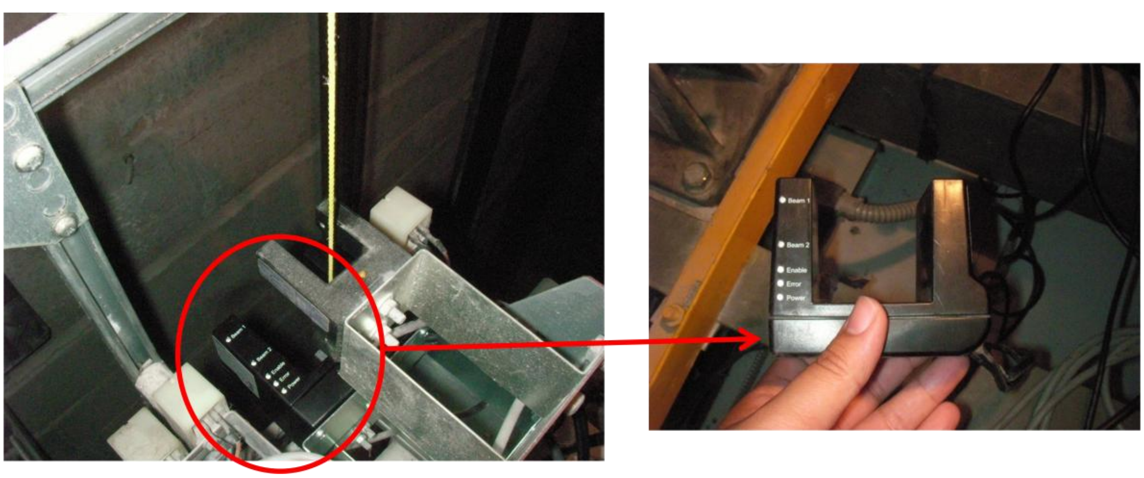

Figure 5.2: PHUET Sensor

The main problem in UTP elevators is that after a while, the alignment between the car door and the landing door runs by 1-2 inches. This problem will pose as a safety hazard. The cause of the problem is frequent travelling up and down of the elevator. The component that is used for the alignment is called the KNR-O PHS Sensor & the PHUET Sensor. These sensors detects whether the elevators are properly aligned on every floor.

Comparing with the elevator manual, these two components are scheduled to be replaced at every Preventive Maintenance (PM) occurrence. But the occurrence of breakdowns due to these two components means that the cause of the problem is that component is not changed at the proper time, not at every PM occurrence. This measure to cut costs has resulted in the two-thirds of the breakdowns.

5.4 Maintainability Factors

Mean Down Time (MDT)	229 min
Mean Time To Repair (MTTR)	211 min
Mean Response Time (MRT)	14 min
Mean Time Between Failure (MTBF)	24020 min
Mean Time Between Maintenance (MTBM)	2503 min
Availability – Achieved Availability (A_a)	91.6%
Availability – Operational Availability (A_o)	82.26%

Table 5.2: Maintainability Factors

The MDT calculated is roughly 4 hours which is acceptable but still needs to be worked on as to minimize inconvenience to the users.

The average time taken to repair a elevator when it breaks down is roughly 3.5 hours which is acceptable as some problems may be caused by very complex reasons, for example, the breakdown may be caused by more than one component failure.

The response time for the technicians to attend to the breakdown is very efficient, which is 14 minutes.

The MTBF calculated is approximately 17 days, which is acceptable as my case study involves 16 elevators. The probability that one of the 16 elevators will fail in 17 days is acceptable.

Based on the availability of the elevators, the achieved availability is 91.6% which meets the requirement of >90%. And as for the operational availability, the elevators are in operation 82.26% of the time which exceeds the requirement of 80% set by the university.

CHAPTER 6

CONCLUSION & RECOMMENDATION

6.1 Conclusion

Comparing the maintainability factors that has been calculated with the standards set, the elevators in the university have met all the standards that have been set. However, there is still much room for improvement as minimize the failures and provide the best service to the users on campus.

The maintainability of the elevators can be improved further if the specifications and details of the manual are followed by the maintenance team.

The elevators in UTP are maintained once a month but the elevators elsewhere has to be maintained, inspect and repaired at an average of once every fortnight. The main cause of the problem is vandalism. Elevators in areas such as flats, condominiums, shopping malls and offices tend to break down due to excessive use, spoilt buttons and indicators, spoilt LCD poster and also by excessive “door-holding” (when people opt to keep the door open by holding the door and not allowing it to close) which spoils the mechanism and sensors.

6.2 Recommendation

The maintenance department needs to improve their method of recording and storing their maintenance records. Their current system which keeps the paper checklists in files is not efficient as the records takes up too much space and it is hard to search through the maintenance records.

A suggestion to improve the maintenance is that the maintenance department implements a “Paperless Maintenance” system where all the records can be collected on a PDA and stored in the database. This would eliminate storage space problems and dishonesty in recording the maintenance works. This system would enable the maintenance department to search through their maintenance records.

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5. "Root Cause Analysis" from http://en.wikipedia.org/wiki/Root_cause_analysis
6. "Fault Tree Analysis" from http://en.wikipedia.org/wiki/Fault_tree_analysis
7. Kenneth Crow, "Failure Mode & Effects Analysis" from http://www.npd-solutions.com/fmea.html
8. Schindler Official Website: www.schindler.com

Appendices

Motor Room

Figure 4.1: Motor Room Door

Figure 4.2: Gearbox & Pulleys

Figure 4.3: Schematic Diagram

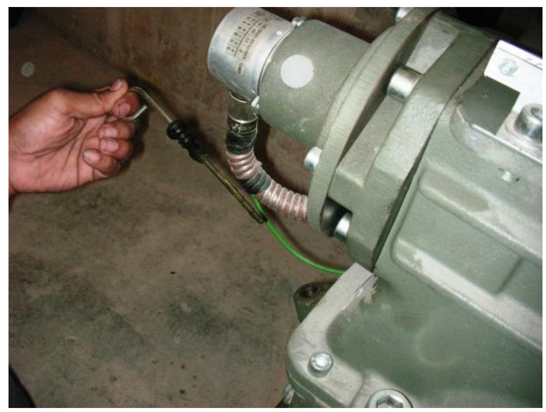

Figure 4.4: Oil Level for Gearbox

Figure 4.5: Gearbox

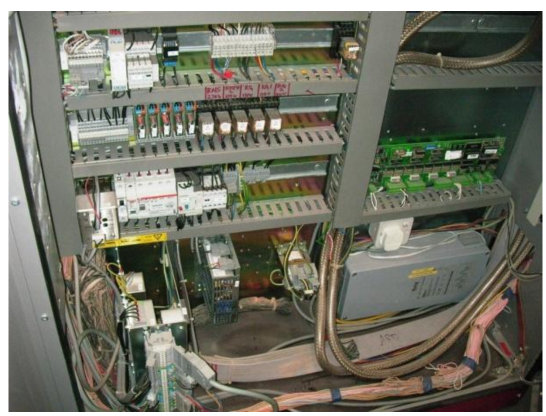

Figure 4.6: Controller

Figure 4.7: Battery for ARD

Figure 4.8: RecallControl Switch

Figure 4.9: Machine Devertor Pulley

Figure 4.10: Brakes for Pulley

Car / Landing

Figure 4.11: Suspension Roller & Track

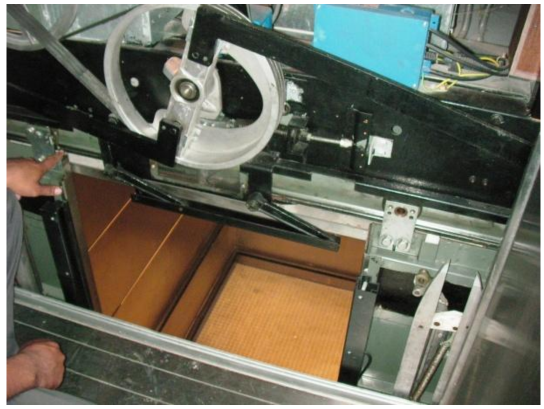

Figure 4.12: Car Door Opened

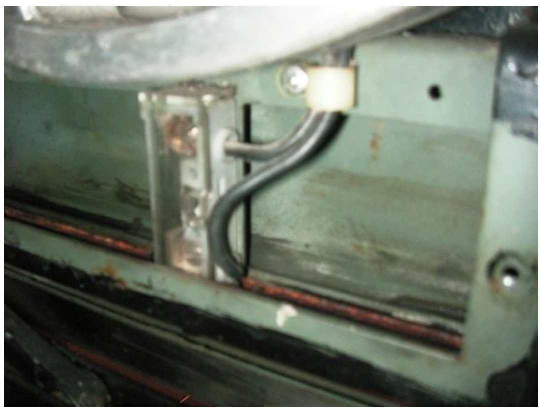

Figure 4.13: Car door safety system

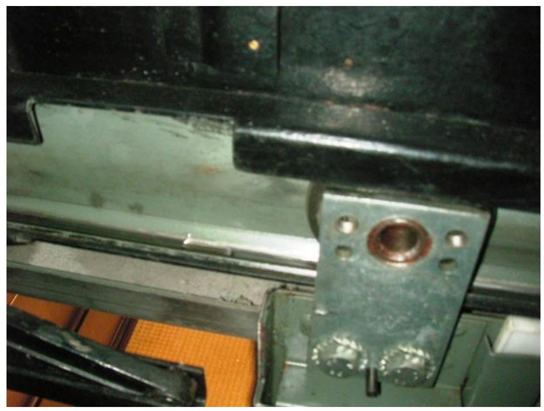

Figure 4.14: Car door contact

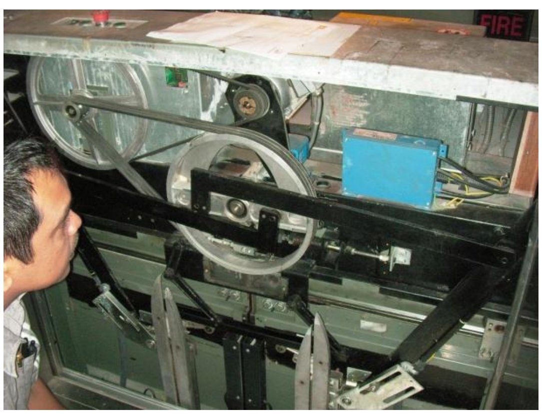

Figure 4.15: Car Door closed

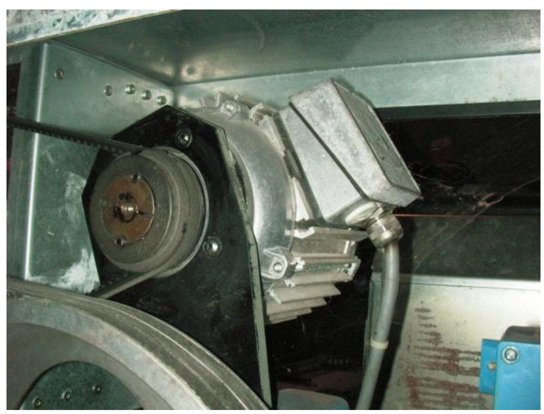

Figure 4.16: Door Motor

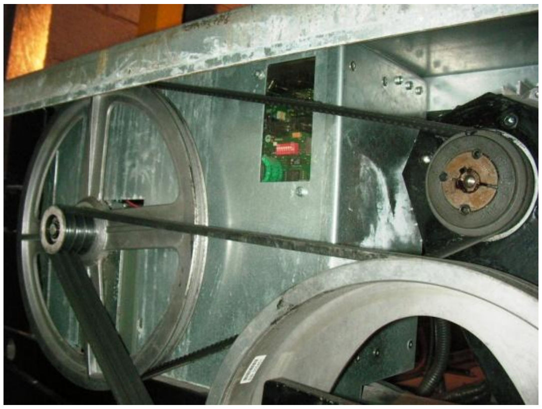
Figure 4.17: V-Belt

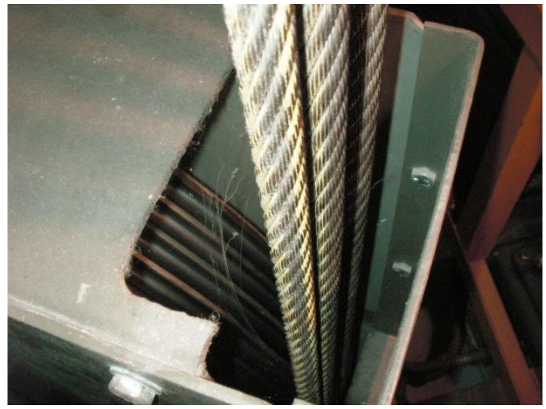
Figure 4.18: Anti-twist ropes

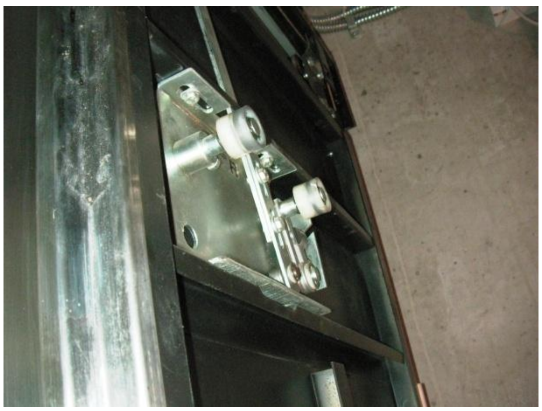
Figure 4.19: Landing sill & shoes


Figure 4.20: Cam rollers

Car Top/Shaft

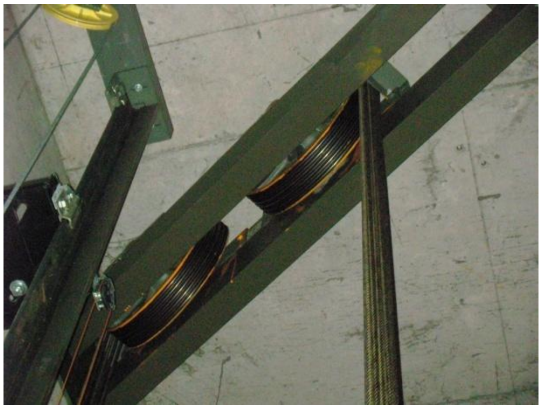

Figure 4.21: Pulley Top Shaft

Figure 4.22: Counterweight

Figure 4.23: Counterweight

Car Bottom/ Pit

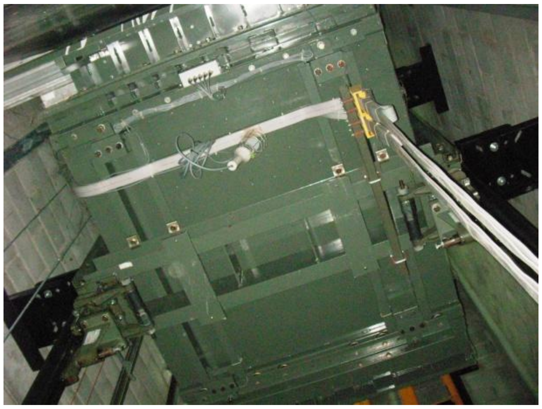

Figure 4.24: Bottom of Car

Figure 4.25: Pit

Gantt Chart

No.	Detail/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Project Work														
1	Meet Maintenance Dept to obtain the PM checklist														
2	Study the Maintenance Checklist of existing elevators														
3	Research Literature Review on Elevators Maintenance														
4	Follow Antah Schindler during PM works to observe														
5	Conduct Motion & Time Study														
6	Collect Maintenance Records from Maintenance Department														
7	Analyze Maintainability Factors														