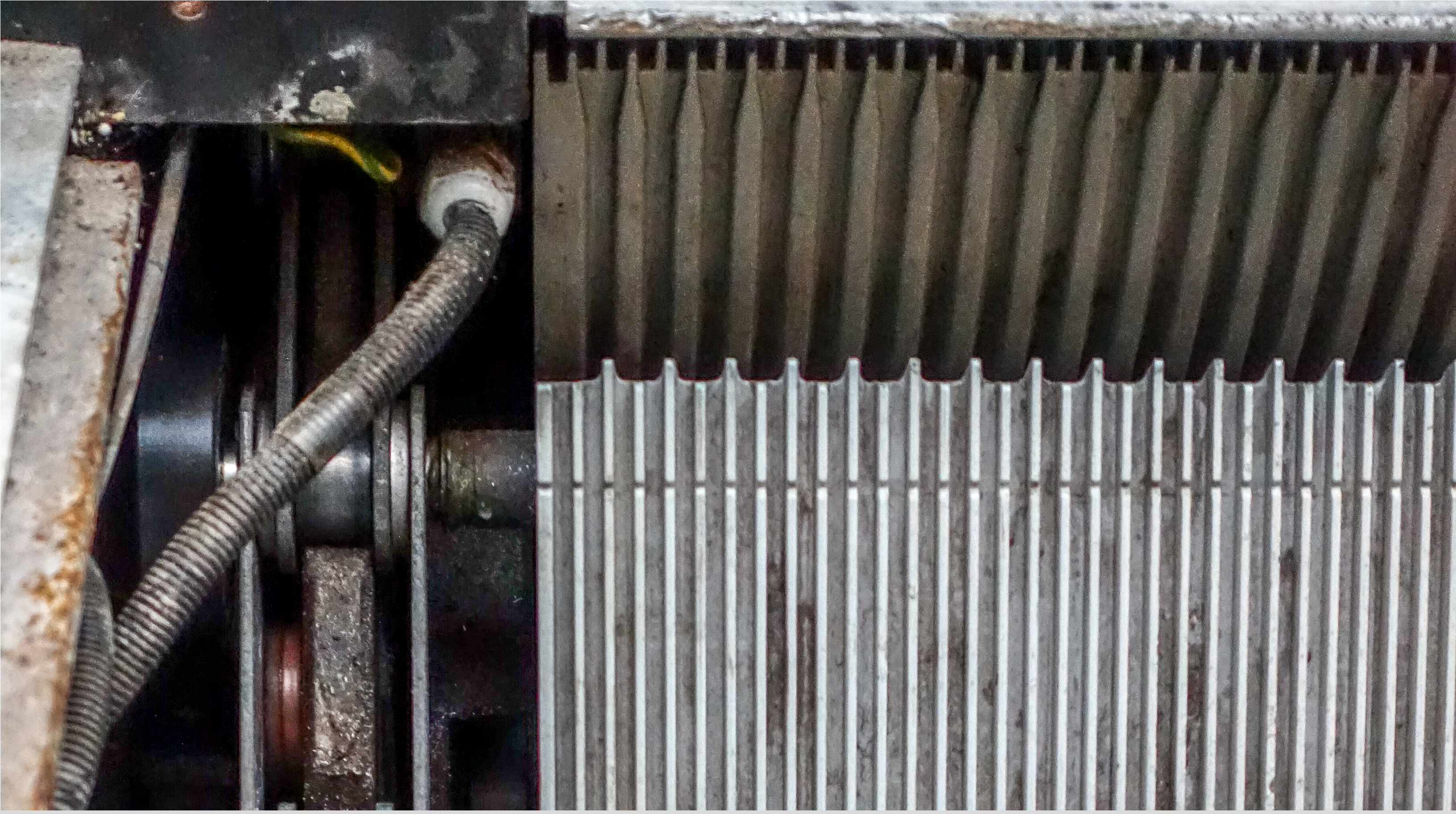
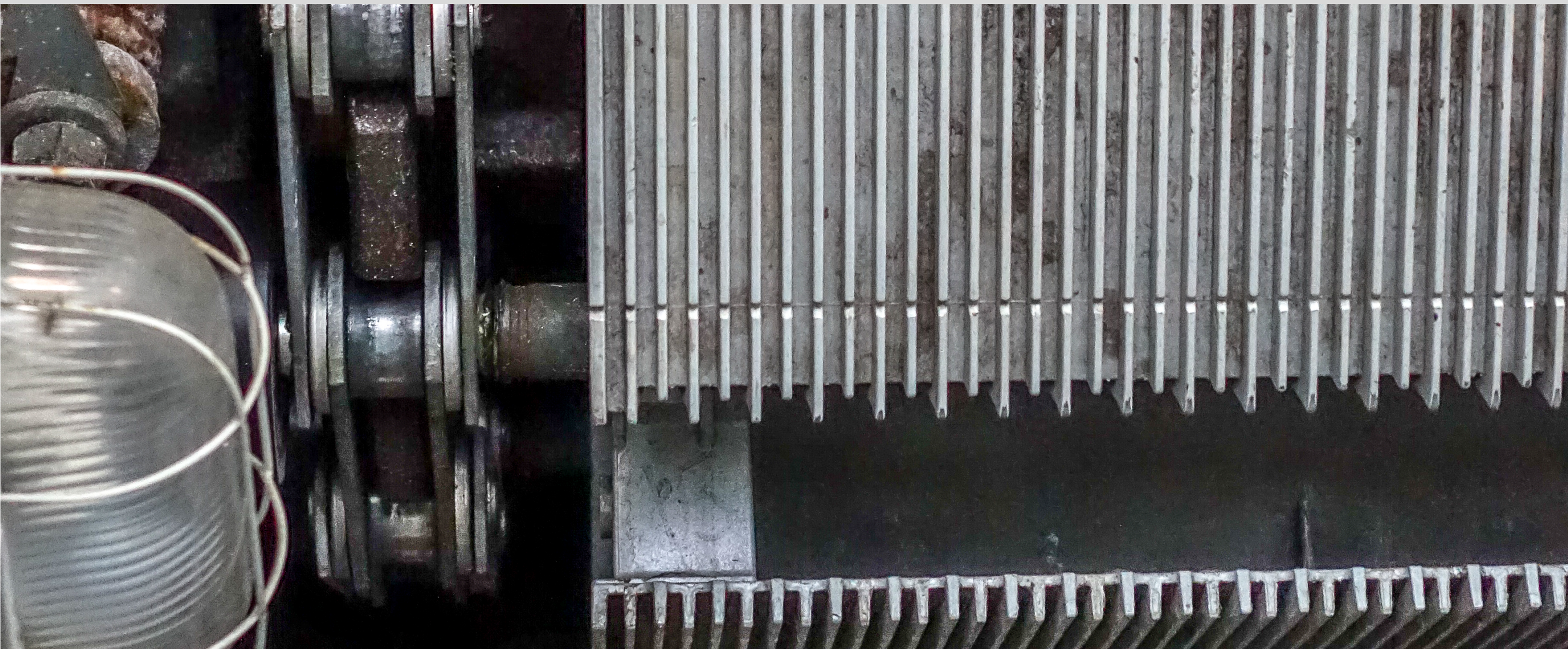


An investigation to find the optimal maintenance interval for escalators based on their usage.

Internship RET NV.

K. ’t Hart - s1001914



An investigation to find the optimal maintenance interval for escalators based on their usage.

Koen 't Hart*

Abstract

To cope with the flow of commuters using the subway every day, the RET N.V. has close to 150 escalators. The commuters are able to move between floors safely and quickly with the escalators. To keep the escalators operating as desired and required, maintenance should be performed on a regular basis. Currently maintenance is outsourced to the original equipment manufacturer but they give no insight in the necessity of the maintenance done nor give feedback with the condition of the equipment. This report will create a tool for the RET which gives them the means to justify the performed maintenance. Using the electric current as a parameter for the load the escalator undergoes and summing this on a period basis. The resulting trend increases in relation to the mechanical losses of the system, an equivalent for the degeneration of the components of the escalators. The optimized maintenance interval is found when the accumulated degeneration exceeds set limits. However due to unclear current maintenance intervals and limits to degeneration an optimized interval was not found. It is recommended to continue measuring current data and find limits by degenerating an escalator until it is close to failure.

Keywords:
Usage Based Maintenance, Escalators, Interval Determination, Load Parameter

MSc Mechanical Engineering, Maintenance Engineering Department, Univeristy of Twente, Enschede, the Netherlands
Internship, Engineering Department, RET N.V., Rotterdam, the Netherlands
***Student Number**: s1001914

Contents

Introduction

The public transit with the subway/tram/bus and one boat in Rotterdam is managed by the Rotterdamse Elektrische Tram (RET). This company founded in 1878 is now responsible for transporting over 600.000 people a day. In 2007 the RET privatized and since then it is a limited liability company, another major milestone was only just achieved as the entire company will run without subsidies in 2017[1]. Several innovative strategy changes have made this possible but a company wide plan was created in 2013. 'De perfect reis' (the perfect trip) which intends to improve on 4 categories of public transit or its governing:

Optimal commuter experience Correct response during delays or disturbances, perception of safety for the duration of the trip and a positive contribution to the environment and society.

High quality Trouble-free rolling stock and infrastructure with competitive costs, minimal impact or disturbances, minimal waste and cost efficiency

Mobility expert Door to door transit and constant expansion

Healthy organization Clear direction, cooperation and innovation

The categories stated above mention topics where modern maintenance solutions can provide tools to fulfill the targets of the RET. These targets are mostly to decrease costs and increase customers satisfaction or profit. Proper maintenance plans such as reliability centered maintenance (RCM) allow costs reduction in maintenance while staying in control of the process[2]. So these plans are constantly reconsidered and redesigned to ensure the availability of the components but for lower costs. In the current plans of the RET there is room for improvement.

To provide the insight to adjust these plans correctly this report will introduce a new approach to optimize the maintenance of the escalators in and around the subway stations of Rotterdam. The result will provide an optimized interval between preventative maintenance for the escalators of the RET based on usage parameters instead of calender time. First off this report will explain the current plan, the frequent failures and the corresponding costs. The frequent failures and their mechanisms are analyzed and related to the usage, load and finally condition of the escalators. Then based on long term measurements of the usage an estimate of the remaining life is derived and the optimized interval is found which will have neither over nor under maintenance. This is done for 2 escalators, one heavily used and the another which undergoes low to medium use.

1. Methodology

1.1 Problem Definition

The current maintenance plan does not take into account the actual usage of the escalators. It is essentially decided by the maintainer and original equipment manufacturer (OEM) that maintenance takes place 8 times per year. These maintenance opportunities are planned by the OEM, performed by the OEM and they decide which component to check at which opportunity. How the OEM determines the schedule and maintenance activities is not shared with the RET. Therefore the RET has set out to implement an approach to estimate the usage of the escalators. This usage is to be measured without adapting the escalator and find a usage parameter relevant to the failures. Simple calculations are then used to determine the accumulated damaged (due to hardware limitations). A simple drawing of an escalator is shown in Figure 1 with some of the parts of importance.

1.2 Main Research Question

"*How can the maintenance interval be optimized if load on the escalator is taken into account?*"

1.2.1 Sub Research Question

1. What is a representative parameter for the load on the escalator?
2. How is this parameter measured?
3. What are the necessary calculations on the measurement to translate it to load?
4. How does this translation relate to the limit load?
5. What is the prognostic remaining life of the escalator?
6. How does this new interval improve upon the old?

1.3 Plan of Approach

The analysis of this project is divided into three parts which contain the following topics.

1.3.1 Part 1

This part investigates the current situation and creates the foundation for further measurements. The maintenance plan, failures and corresponding costs are explained of the current situation are explained. The failures are related to corresponding failure mechanisms which in turn are detected by measuring the relevant parameter. A literary study is performed to validate the use of this parameter.

1.3.2 Part 2

With the foundation established, part 2 will continue with the validated parameter and confirm its application by performing a proof of concept. The parameter is measured for several days on several locations after which necessary calculations are shown to determine the daily load on the escalator.

1.3.3 Part 3

Part 3 will explain what the limit of this daily load is and this indicates the optimized maintenance interval. Other opportunities and measurable parameters are included to back up the calculations and provide a higher accuracy of the calculated interval. Lastly further possibilities are supplied for the RET to pursue.

2. Analysis

2.1 Part 1

2.1.1 Current Maintenance Plan

The maintenance plan of the RET now is calendar based maintenance. The escalators are regularly inspected and maintenance is done 8 times per year. At these maintenance opportunities one of several modules are performed (shown in Appendix B). The modules consist of a set of checks per component of the escalator. If a component is found at fault it is repaired on the spot. Planning the modules is done by the OEM and this is given up to a year in advance to the RET. That gives the RET enough time to arrange the necessary budget.

The RET has planned large scale preventative maintenance after a service life of 7 years and 13 years is reached. After 13 years the chain and other critical components are preventatively replaced. After 25 years the end of life is reached for the escalators. However they experienced that with the current maintenance plan the life cycle is much longer due to proper upkeep of the escalator.

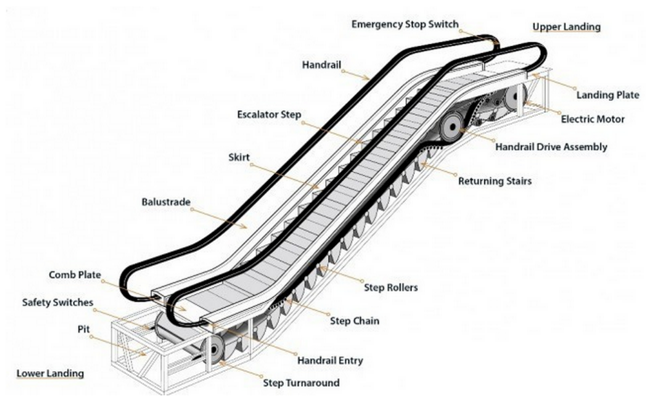


Figure 1. Basic drawing showing some components for any escalator.

Frequent Failures In 2015 KONE went out to repair escalators which gave error codes 668 times. These visits do not necessarily mean actual repairs are done. It occurs quite often that the escalator is running by the time they arrived because it automatically resets itself. If these visits are sorted into what are repairs relevant to this report only 46 repairs are left. There are so few remaining as a lot of the repairs are caused by vandalism or other non mechanical/electrical issues. The failures are shown in Appendix A in a fault tree analysis (FTA). The most frequent failures are related to the combplate of the escalator. These plates are at the bottom and top and remove thrash from the steps and keep clothing and fingers from dangerous areas. However it often happens that the combs break or things get stuck which can cause severe damage to the escalator.

More failure data is difficult to interpret because the RET is dependent on KONE for its reports on what repairs are performed for which failures. The other course of getting the information is from the error report generated by the building management system (BMS). However this system also lacks the detailed failure information. The inevitable consequence for the RET is that it leads to a lack of documentation in their failure database. This is a problem when estimating the condition of the escalator. Also it is difficult to relate the failure to the specific damaged component and more so to the failure mechanisms, which are described later. Another consequence is the lack of reasons the RET has in the arguments to condone or refuse the costs of the maintenance performed.

Costs The RET contracted KONE, in this case also the OEM, for almost unconditional maintenance. In this contract it is written that KONE pays for the correction of all failures of the escalators. The exception is costs contributed to vandalism, often there is discussion between the OEM and RET about the responsibility for the repair. Costs per month for one of the more busy stations in the city is around €7000, which includes the fixed costs of the planned maintenance and the variable costs due to vandalism. Costs per month vary between the €4000 and €7000 per station and there are 57 stations in the RET's care. Which adds up to a large share of the yearly maintenance budget.

The costs of replacing critical components at the mentioned maintenance intervals also adds up to large amounts of money. The chain for example is €120.000 to replace while a new escalator is around €250.000[3]. However the costs for the frequent failures related to mechanical and electrical components is limited to around €45.000 per year. A crashed escalator caused the most expensive failure, around €3500, because the chain broke ruining several steps. The cheapest failures are less than €100, however this information is somewhat distorted as some of these failures should be costlier except the clever stocking of spare parts circumvented the need to acquire the components at higher costs. Also the costs contributed to handrail failures is neglected in this database.

Failure Modes/Mechanisms Due to the components inside the escalator the failures can be sorted in the following categories: mechanical, electrical and external factors. External factors include the uncontrollable outside influences such as weather effects, vandalism, dirt/grime and human errors. These are neglected in this report although they are responsible for more failures in comparison. The remaining categories can also be called external system loads. The corresponding internal loads of mechanical and electrical are stress/strain and electric field/current/voltage respectively. These loads govern the system and cause the failures according several failure mechanisms[4].

The failures in Appendix A are caused by corresponding failure mechanisms. Due to the design of the escalator the main mechanisms are part of the mechanical or electrical external loads. The most common mechanisms are wear, fatigue and fracture for mechanical loads. For electrical loads its ageing of connections, arc flash and creep current (short).

2.1.2 Relevant Parameters

These failure mechanisms are the underlying physical mechanisms causing the failure of the component. The relevant parameters should be connected to these failure mechanisms

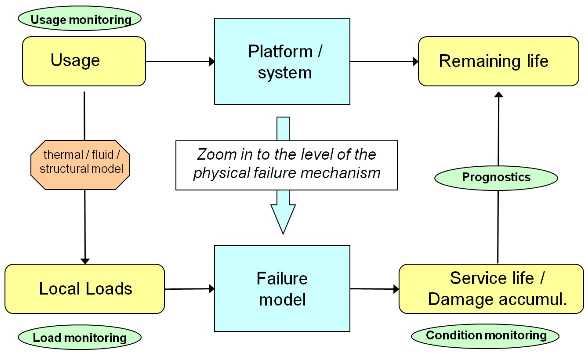


Figure 2. Flowchart which shows the relations between usage of, loads on and condition of an asset[4].

per component, this proves difficult for the electrical failures as the root causes are hard to determine. In Appendix A the failure mechanisms are linked to the failures. These are the mechanisms related to the components of the escalator[4]. Wear is the movement between two or more parts with physical contact which cause a loss of material at the surface of one or both bodies. While deformation is the warping of the component such that it cannot fulfil its function or suffice its precise dimensions requirements. Static Overload or fracture is when the applied load exceeds the static strength of the material. Fatigue is when a repetitive load will, after a number of cycles, reduce the static strength of the material such that a normally safe stress level causes a fracture. The next mechanisms are electrical: ageing where longer exposure to current causes an elevated temperature which causes an accelerated deterioration of the material. Creep current is when excessive currents cause overheating and the eventual failure is melting, evaporating or cracking of the conducting parts. Partial discharge occurs when a parts breaks down but not completely causing strange behaviour of the components. Finally human error is when people knowingly or unknowingly apply wrong techniques, tools or parts which cause the failure. These are some of the mechanisms which cause the change in behaviour of the escalator.

For some behaviour the following parameters can be chosen to measure degeneration: deformation of the chain, vibration in the bearings of the steps and tension in the chains turnbuckle. If these parameters are measured one applies condition monitoring. However measuring these parameters requires sensors applied to moving parts, and transmit the recorded data wireless. This is not possible for the escalators of the RET due to inspection rules. Any modification done to the escalator or its components will require a full reinspection before it is allowed to operate again. Besides the sensors are costly to implement on rotating machinery.

The chosen parameter should be measurable without modifying the escalator. In Figure 2 the escalator is assumed as a black box (platform/ system). It shows the types of monitoring at different levels and what specific parameter is to be measured. It is not possible to move from usage to remaining life because of many uncertainties such as technical limitations and a lack of understanding of the physical relations. To estimate the remaining life the longer way around has to be taken. If a proper relation is determined between the levels usage, local loads and service life/damage accumulated precise estimates can be made for the remaining life and the maintenance interval. The move between monitoring strategies will have a negative effect on the accuracy of the predicted maintenance interval except when using these proper physical relations or appropriate models to model the move. An advantage of monitoring usage instead of condition is that the required sensors are more straightforward and thus cheaper. Also usage monitoring can be done from further away from the actual moving component which is good because modifying the escalator is not an option. In the project initiation document created by the RET an assumption is made that the current would be an accurate parameter for the failure mechanisms in the escalator.

2.1.3 Literary Confirmation

To confirm the assumption made of the parameter a literary study is performed.

Al-Sharif states in his article that the main factors in daily energy consumption are rise, machine type, number of commuters and the direction of the commuters (up or down).[5].

He continues by explaining how the energy losses an escalator experiences are either fixed or variable. Fixed losses are contributed to friction and inefficiencies in the motor or gearbox while the escalator is not loaded with commuters. Then there are variable losses which occur when commuters are on the escalator. With these losses it matters if the escalators moves up or down. For a downwards moving escalator the consumed energy goes down because potential energy of the commuter is put into the escalator. The energy consumption decreases as more commuters are on the escalator. The consumption eventually becomes negative and starts regenerating energy back into the net. That point where this transition occurs is named the crossover point. An upwards moving escalator accordingly consumes more energy as more commuters are using it.

Lastly the paper shows that the amount of current drawn does not differ if the commuter walks or stands on the escalator. Only the time this current is drawn is shorter for the walking commuter. The case of Al-Sharifs is relevant because the current is directly responsible for energy consumption.

Uimonen, in his thesis work, measures the consumed energy and gives a power breakdown of an upwards and downwards moving escalator with two persons as load[6]. Which basically confirms what we have set out to find. An interesting aspect is the similar power consumption when the escalator runs down or up unloaded. Extra commuters on the escalator will draw more power. Energy consumption proves to be an excellent representation for the load on the escalator. The current drawn can be related to the energy consumption which is a positive sign for us.

An article written by Wiedenbrug from SKF presents three

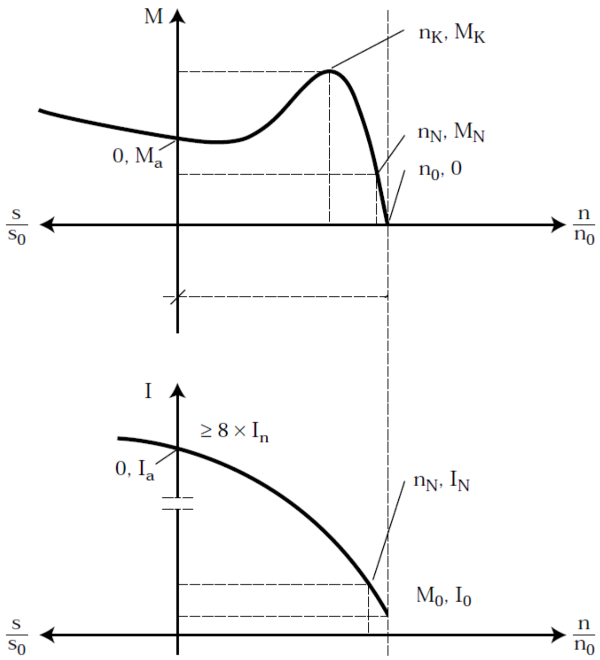


Figure 3. Characteristic plots of the torque and current from an electric motor, plotted against the ratio of revolutions per minute[8].

different case studies which indicate the possibility of using torque as a predictive maintenance tool, which proves to be a successful indicator of damages in a pump as explained in case study number two[7]. Before maintenance was performed the torque output was 40% lower than the original specifications. Furthermore the pump showed an unsteady operation state which was out of line with the non damaged pump. Large faults were detected after initial inspection which required the pump to be removed from operations. In our case the torque can be controlled directly by current supplied with the frequency drive.

Danfoss provides an extensive guide to frequency drives and electric motors containing several interesting topics[8]. The relation of torque and current with respect to the ratio of revolutions per minute of the rotor and the electrical field, shown in Figure 3. The figure shows the nominal torque M_N where the motor is at nominal speed, kip torque M_K which is maximum torque at nominal voltage/frequency and the start-up torque M_a the torque which is provided from standstill. The operating region of the motor is between $0 < \frac{n}{n_0} < 1$. Where if the revolutions per minute are lower than n_k it is in the start up region and for higher revolutions it is in the work region. In the work region, which is around n_N, the relation between current and torque is almost linear.

Furthermore it states that the torque of the motor is not only spent on load and mechanical losses but also on motor inefficiencies.

Summary We have learned that the escalator experiences two types of losses: fixed and variable. That the energy consumed by these losses is created by current drawn by the electric motor. The consumed energy increases when the escalator is loaded and moves in the upwards direction. The reverse applies for moving downwards. The relation between current and torque is linear for the working region of the escalator. Finally we can state with more certainty that the current is an accurate parameter for the fixed and variable losses in the system.

2.2 Part 2

2.2.1 Measurements

Measurement 1 For the first measurement the current used by the electric motor of the escalator will be logged. This escalator is subjected to a low/medium load of commuters. The current is logged for 6 days while the escalator is in normal operations even though Christmas days are included. The following section explains the set-up and results of the experiment.

Set-Up The escalator at Troelstralaan in Schiedam is controlled by a frequency drive. It varies the frequency and voltage to control the speed and torque of the motor. When the torque varies the current through the stator loops in the motor also varies. This drive in particular provides a parameter output of the current used by the motor. Using a laptop and serial connection (RS-232) it is possible to log the current data for periods of time[9]. The advantage measuring the current with this connection is the low cost and ease of the measurement. Furthermore all escalators with an Omron frequency drive can be read out in the same manner. This enables us to get a quick estimate of the current drawn and confirm the expectations/assumptions

Processing The current data shown on top in Figure 5 is integrated according to trapezoidal rules shown in the following equation:

$$\int_a^b C \approx (b-a)\left[\frac{c(a)+c(b)}{2}\right] = L \tag{1}$$

Where c is the level of current measured and the subtraction of a and b is the interval between measurement points which in this case equals one. L is the load per time step and summed over the entire day.

Results In the detailed plot, shown on top in Figure 5, the current curve is shown with several specific points of interest. First off there is the start peak where the frequency drive responds to the light sensor input. Which is followed by the accelerating region where the mass of the escalator is brought upto operation speed. When the correct speed is reached the current is lowered and kept constant to provide a constant traveling speed for the commuter across the escalator. Small increases or decreases are due to commuters entering or leaving the stairs. Finally the last peak is the current required to bring the escalator mass to a halt again after the last commuter leaves it.

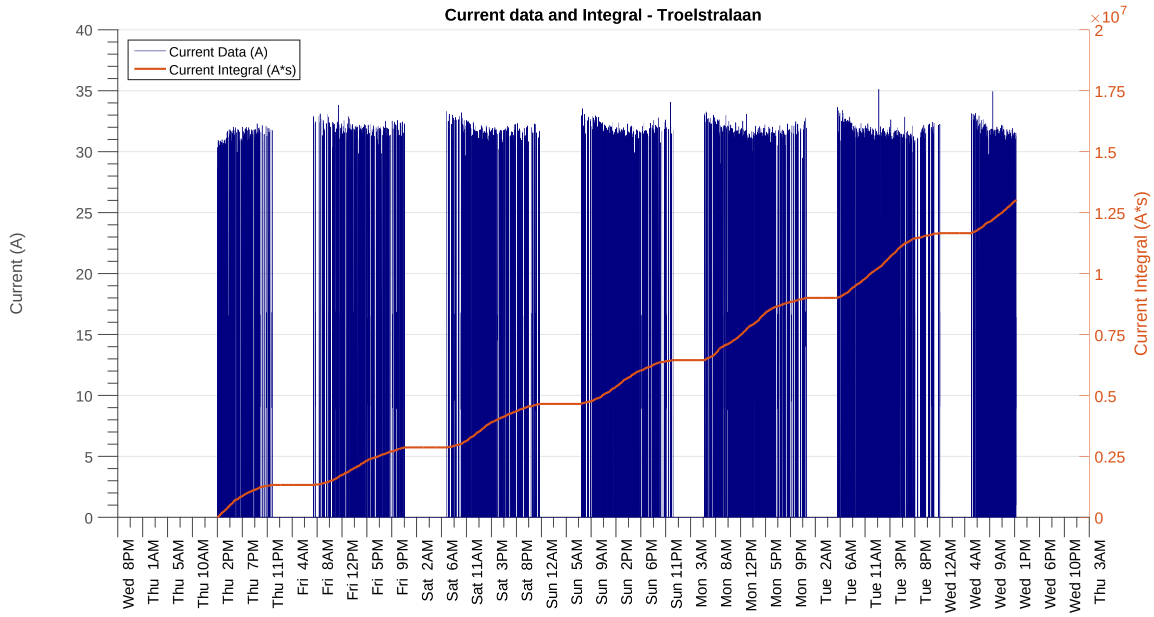


Figure 4. The current drawn by the electric motor(red) and integral of the current data(blue) on Troelstralaan.

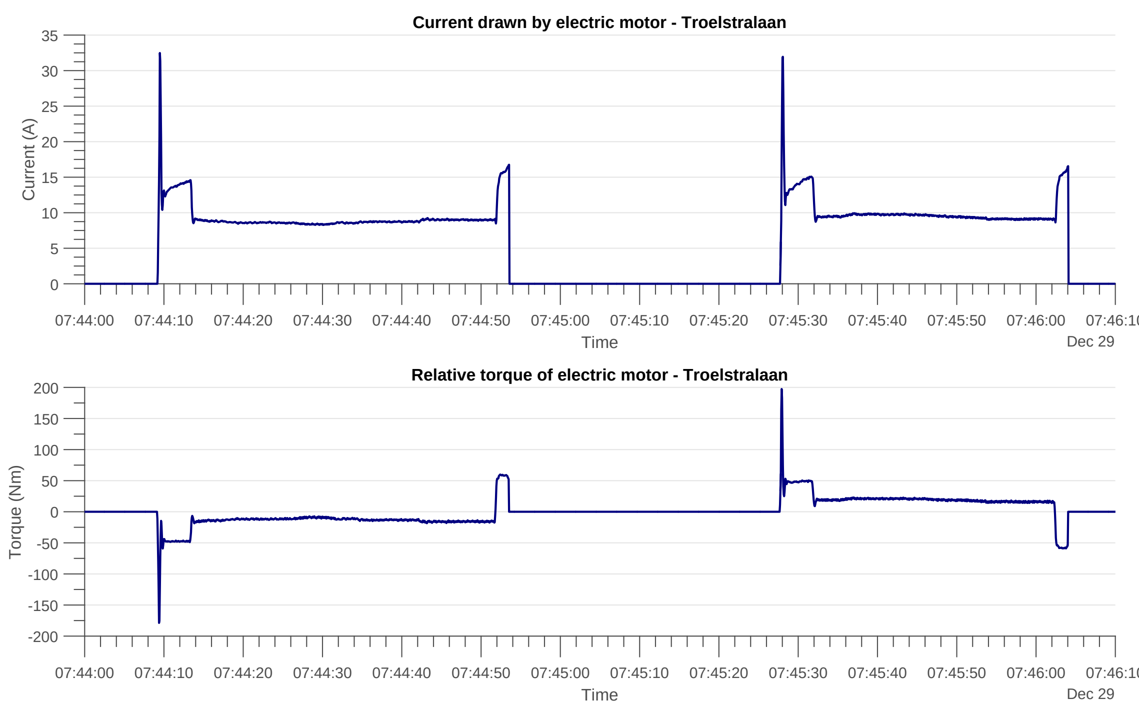


Figure 5. Details of the current drawn by the electric motor.

The bottom plot in Figure 5 shows the relative torque. Defined as the torque compared to the rated torque of the electric motor. Although it is larger than 100% when starting the escalator only does so for short periods of time. This curve indicates if the escalator runs up or down. In our case the first response is down (negative torque) and the second is up (positive torque). The relevance to our case is as stated in Uimonens thesis but for energy consumption: the current decreases for every extra commuter moving down and increases for every commuter moving up.

Note that in the top plot in Figure 5, for the second response we can see two commuters moving up followed by a third.

In Figure 4 the continuous sum of the integral is shown. Interesting points are the increase of the first day of work (Monday) and its rush hour traffic point around 8AM. Furthermore the increase difference between Christmas days (Friday and Saturday) and working days is substantial. The outliers in Figure 4 are caused by rapid switching between running up and downwards. The summed daily integrals are shown in Table 1, here the difference between Christmas days and working days is clearly shown.

Another interesting results from the measurement is the change in peak current. In Figure 4 the current data shows a higher peak current in the early mornings as opposed to midday. This is be caused by the solidification of grease and lubrication which is due to long periods of standing still and colder temperatures. The peaks can only be reduced by running the escalator for some time. The average per day is shown in Table 1. From that plot we can see that the peak current average is higher on days when the escalator is used less. The difference between Thursday and Wednesday is due to the start and stop time of the measurement. Wednesday measured the morning while Thursday measured the afternoon.

Measurement 2 The second measurement will use a similar set-up as the first. The difference being the load on the escalator. The escalator in Zuidplein metro station is continuously running downwards and used by more commuters each day than Troelstralaan. This is caused by commuters going to a hospital, an event hall, a shopping mall and the second busiest bus station of the Netherlands.

Set-Up This escalator is specifically chosen for its Omron frequency drive. This drive is identical to the drive at Troelstralaan and allows us to log the current using the same methods. The current is logged for 7 days to compare it to the first measurement.

Results Despite choosing escalators with similar frequency drives the behaviour is different. First of all in Figure 6 the escalator is not turned off for 3 nights, only after the fourth night the escalator is shut down. This is also apparent from the high start-up peak on Friday morning. This could be explained by the peak on tuesday morning where the shut down did not work properly. The overall shape of the curve is similar to the detailed look of the first measurement, shown in Figure 5, but then spread over the entire day. Furthermore after the escalator is turned on after being shut down for the night it takes several hours for the operating current to lower back to approximately 4.7 A. This is due to the solidification of lubrication during the period of standing still similar to the escalator on Troelstralaan.

In Figure 7 the current is shown which is caused by the usage of commuters. The escalator is running downwards with a level current of about 4.7 A to 5 A. As soon as a commuter enters the escalator the current peaks to accelerate the mass to safely move the commuter downwards. After the commuter leaves the mass is decelerated and the escalator returns to its level current. In this case the escalator is always rotating and only shut down at the end of the day. An interesting even occurs around 8.39 AM where the escalator is loaded up to the point the motor has to intervene. The motor generates positive torque to keep the commuter and escalator mass from accelerating downwards. Still the relation between the number of commuters on the escalator and the current drawn seems the same as the at Troelstralaan.

The results of the integral calculated from the current data is shown in Table 1. There is a clear difference in surface area per day between week and weekend days as was the case in measurement 1. Monday especially was a heavy day as students returned from spring holidays for the first day of the new semester. For the peak current the same holds as measurements albeit with smaller margins. Where the peak current for the Troelstralaan differed 0.35 A at best Zuidplein only differs 0.1 A at best. These smaller margins can be explained as both escalator function differently and the peak levels are different because of this.

2.2.2 Relation Usage/Load/Condition

The escalator calculations assume the escalator is in static or constantly moving state. If the motor can reach these states it can also accelerate and decelerate the same mass. This calculations takes the weight of the commuter m, angle of inclination θ, linear speed s and efficiency η_e to determine the required power of the motor to move the escalator[10].

$$P_s = \frac{m \cdot g \cdot sin\,\theta \cdot s}{\eta_s} \tag{2}$$

This is power is related to the power consumed by the electric motor for which the following equation goes:

$$P_w = U \cdot I \cdot \sqrt{3} \cdot cos\,\phi \tag{3}$$

Where U is the voltage, I is the current, $cos\,\phi$ is the phase shift between actual and rated power. So this allows us to determine the relation between mass on the escalator and current drawn by the electric motor. Which is a linear relation which has a starting value corresponding to the current drawn when the escalator is unloaded C_h.

$$I = \left(\frac{g \cdot sin\,\theta \cdot s}{\eta_s \cdot \sqrt{3} \cdot cos\,\phi \cdot U} \right) m + C_h \tag{4}$$

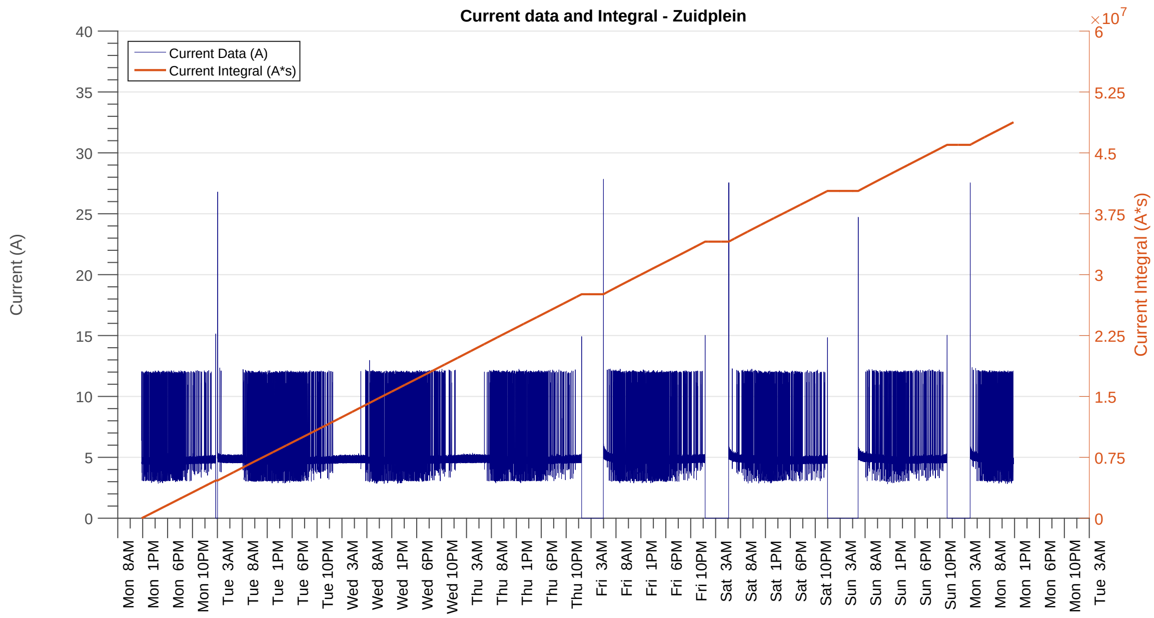


Figure 6. The current drawn by the electric motor(red) and integral of the current data(blue) on Zuidplein.

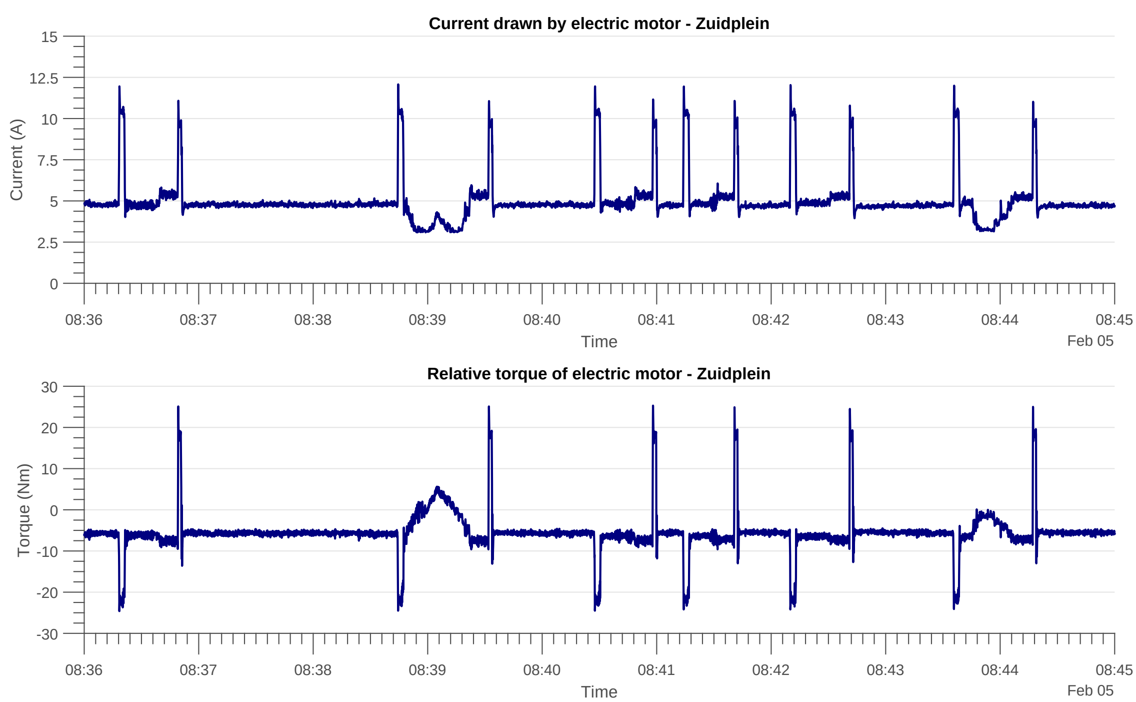


Figure 7. Details of the current drawn by the electric motor.

Day	Integral Troel (10^6)	Integral Zuidp (10^6)	Average Peak Troel (A)	Average Peak Zuidp (A)
Monday	2.55	8.38	31.48	10.60
Tuesday	2.65	7.12	31.36	10.55
Wednesday	1.37 (Morning)	7.65	31.39 (Morning)	10.57
Thursday	1.33 (Afternoon)	7.23	31.04 (Afternoon)	10.59
Friday	1.54	6.48	31.71	10.60
Saturday	1.79	6.24	31.56	10.64
Sunday	1.80	5.68	31.66	10.62

Table 1. Table summarizing the daily integrals and peak currents.

This calculations assumes there is no phase shift between the actual power and the rated power of the electric motor so $\cos\phi = 1$. It has to be noted that this is the current when the mass is moving with constant speed. The mass is already accelerated and in equilibrium. The negative mass indicated commuters moving down the escalator.

Summary Now we know the current drawn by the electric motor and how much mass this moves on the escalator. We have seen the characteristics for two different escalators. Also we found that both the zero load current and the peak current are indicative of the load of the system as well as the integral is for the use. In case of the zero load current it will increase as mechanical losses increase. The peak current averages per day are lower for busier days.

2.3 Part 3

The final remaining connection to be made is between the load and accumulated damage/ service life. The mechanical losses in the escalator need to be calculated based on the current measured or mass calculated.

2.3.1 Service Life/ Accumulated Damage

Accumulated damaged is difficult to ascertain since the uncertainties in the relation between load and condition are large. The load on the escalator could indicate the degradation of several components. Each of these components would require a extensive study to determine the physical relation between current/mass and any of those components failure modes and mechanisms. We can safely state that the current is higher when their are more mechanical losses inside the system. However due to the complexity of the escalator it goes beyond the scope of this report to determine each single one.

A way to determine the relation between current and mechanical losses to stop performing preventative and corrective maintenance. This should expedite the degeneration which allows limits to be noted. The OEM will continue inspecting the escalator but refrain from maintaining it. This should go on until failure or until the escalator is non complaint with safety standards. At which the drawn unloaded current when unloaded is the limit the RET should allow on this escalator. This current can be monitored and reported on a daily basis. The increasing mechanical losses will become visible in the increase in unloaded current.

If this approach is chosen limits for both the unloaded current and the integral limit can be determined. The interval will also become clear as the time of exceeding the limits can be predicted.

2.3.2 Maintenance Interval

First off it should be mentioned that the modules mentioned in subsubsection 2.1.1 contain several tasks which are not relevant to the current drawn by the electric motor. This fact changes the maintenance interval per component as the 8 maintenance inspections do not cover all modules. Determining one maintenance interval per escalators because of this is complicated. A reasonable solution could be dividing the maintenance tasks between those relevant to mechanical components and others (vandalism and external influences).

The modules performed by the OEM are shown in Table 2 and Appendix B shows what the modules entail and which components are inspected of the escalator. Appendix B also contains the reporting document of the OEM which is lacking in details of what tasks within the module are actually performed. Already an improvement would be to make the OEM give feedback about the performed tasks. If Appendix B would be expanded with checks per module at least or a rating system at most the RET can start investigating maintenance patterns. These patterns are now lost in the lack of reporting. Furthermore several points are not related to mechanical nor electrical parts of the escalator. If this distinction is applied that the modules: brake (rem, R), combplate (kamdrager, O) and cleaning (schoonmaak, P) can be neglected.

In Table 2 the maintenance schedule for Zuidplein is has a set core of the BKOR modules and every other month GP is performed (2 month interval). The other month is either V or H alternated which is a 4 month interval.

2.3.3 Optimized Interval

The gained knowledge of the escalator system and its behaviour has given insight in what is still missing to determine the optimized interval. The optimized interval is the predicted time before the unloaded current and integral parameters exceed the set limits. However sadly these limits remain unknown. To determine this a long term experiment should be started in cooperation with the OEM.

Another point of interest is the risk accompanied with changing the interval. Due to the uncertain effects of the maintenance tasks it is dangerous to change those. The safety

	1	2	3	4	5
Zuidplein	BKOR-H (9-1)	BKOR-GP (27-2)	BKOR-V (8-4)	BKOR-GP (1-6)	BKOR-H (7-7)
Troelstralaan	BKOR-VG (6-1)	BKOR-GP (4-2)	BKOR-V (2-4)	BKOR-GP (8-5)	BKOR-GH (23-6)

	6	7	8	9	10
Zuidplein	BKOR-GP (24-8)	BKOR-V (23-10)	Inspection (23-10)	BKOR (26-11)	-
Troelstralaan	BKOR-GP (6-8)	BKOR-V (28-9)	Inspection (16-10)	BKOR (1-12)	-

Table 2. Every maintenance inspection and the performed modules of the escalator in 2015.

of the commuters is at stake and it can only be assumed irresponsible. As soon as the consequences of the maintenance tasks are explored further the change in interval can be supported without endangering the commuters.

2.3.4 Continuation

This does not mean the desired result is unreachable. The insight in the behaviour of the electric motor gives the RET the possibility to create a long term measuring device which transfers its measurements from the remote locations. The measurement involve two data-points: the integral of the entire day and the unloaded current. The unloaded current should be measured without commuters on the steps which proves a challenge on its own. The BMS can set the escalator's status as available from a remote location and is reliant on a signal from the light beam sensors to start running. These two data-points are measured every day for up to 6 months on several (up to 10) escalators. Still these measurements are meant to find the limits of these two data-points so this means the escalators should deteriorate up to the point they almost fail. Then there are four scenario which could occur:

- Failure does not occur but inspection puts the escalator at severe risk of failure within several days. Limits are now known.
- Mechanical or electrical failure occurs. Limits are now known.
- Failure occurs but it is not relevant to mechanical or electrical parts. Repairs do not cover any mechanical or electrical parts. Measurement can continue. Limits are not known.
- Failure occurs but is not relevant to mechanical or electrical parts. However repairs involves those parts. Measurement cannot continue and limits are not known.

The last scenario is the least favourable as it will ruin the measurement. This makes this experiment risky as this scenario cannot be negated. Also limiting these chances is not possible.

This 6 month measurement results will be two curves. The integral measurement will be a linearly increasing one. Values will not differ much between weeks except for holidays or special events as demonstrated in measurement 1. This curve will steadily increase until the limit is reached. The interval is easy to determine with the help of extrapolation. The unloaded current relation is probably more complex. With the current knowledge it is not know exactly how this will grow as mechanical and electrical losses increase. Still the same applies here as for the integral that the interval is the time it takes for this unloaded current to exceed the set limits.

3. Conclusion/ Recommendations

3.1 Conclusion

On beforehand the current drawn by the electric motor was assumed to be a correct parameter to estimate the load. This assumption is validated by a literate study. Several interesting sources are found which confirm the possibilities using current as parameter for usage monitoring. This parameter is measured either via current transformers and a data logger or with in our case a output from the frequency drive. The load in kilograms is than derived from the current with equations supplied by Al-Sharifs articles. The relation between current and the mass is a linear one. Another description for the load is the integration of the current data to provide an indication of the daily load. A larger surface below the curve indicates a busier day as more starts and longer runs increase this surface area. The limit to this surface is to be determined experimentally, the physical derivation is too intricate due to the mechanical complexity of the escalator. However the limit can be determined with a long term experiment of up to 6 months. In this period no maintenance is performed but the escalators are closely inspected to find the limits before the failure occurs. After the experiment is done the prognostic remaining life is known. Then the interval is too if the feedback from the OEM is improved.

So this leaves the answer to the main question which was "*How can the maintenance interval be optimized if load on the escalator is taken into account?*". Unfortunately this can only be answered partly. Using the current the maintenance interval can be optimized however the exact number is yet to be found for the escalators considered in this report. The experiment explained should provide even more insight into the limits before failure which will result in the optimized interval, however question can be asked about the effectiveness of the solution and the efficiency considering the costs of implementation. More transparency in the performed maintenance by the OEM should clarify the current maintenance intervals per component.

3.2 Recommendations

Research concerning the unloaded current of the escalator should continue. Only with a long term experiment the relation between mechanical/ electrical losses and unloaded current will become apparent. This relation is a better approximate of the condition of the escalator although due to constraints difficult to measure. However before any changes are made to the interval the RET should be certain of the possible consequences of damage to the equipment and safety for the commuters.

For the monitoring device a PLC with current transformers will suffice. The PLC can be programmed to upload the unloaded current and integral on a daily basis into the already present BMS. Optional are additional sensors for temperature or humidity. These parameters might explain certain behaviour of the escalator better i.e. starting up from a cold morning or running outside in constant rain. There are more parameters which could be measured but due to their technical nature they might not add enough value to be worthwhile of investing.

Another recommendation is to expand the document which records the performed maintenance. The current documentation is too basic for any analysis to improve maintenance. The RET is unable to determine the benefits achieved with the new maintenance plan if they decide to change it. The documentation can easily be improved by including feedback about the performed tasks. If a rating (0 to 5 for instance) is supplied per maintenance task the RET can be alert for patterns related to maintaining their escalators. Also improving their limited database enables a more accurate prediction of the remaining life of the escalator. Better still is the implementation of immediate reporting with the help of modern electronics (tablets).

Finally I can recommend to redo estimated savings attributed to this project. Estimations in the project document are highly exaggerated and should be restored to lower values. The costs of the components might be high but of the individual repairs the costs are closer to the amount in this report. The large deviation in savings could be explained by spare parts costs for instance replacing a chain is €120.000 and postponing this a year ”saves” that amount. Also the investment costs can be reduced if the measuring PLCs are strategically applied such that the smallest amount of PLCs is required.

References

[1] Bastiaan Nagtegaal. Kaartjes tram en metro Rotterdam snel subsidievrij, 2015.

[2] J Moubray. *Reliability-Centered Maintenance*. Industrial Press, 2001.

[3] S C Plotner. *Building Construction Cost Data 2016*. RS Means inc., 2015.

[4] T. Tinga. *Principles of Loads and Failure Mechanisms - Applications in Maintanence, Reliabilty and Design*. 2013.

[5] Lutfi R Al-sharif. Experimental Investigation into the Effect of Mechanical Design of an Escalator and Passenger Loading on its Energy Consumption. In *World Congress on Engineering*, volume II, pages 3–8, 2008.

[6] S. Uimonen. Energy Consumption of Escalators. Technical report, Aalto University, 2015.

[7] Ernesto Wiedenbrug. Predictive Maintenance of Mechanical Failures using Electrical Measurements for Instantaneous Torque. A Modern Approach. Technical report, Baker Instrument Company, 1999.

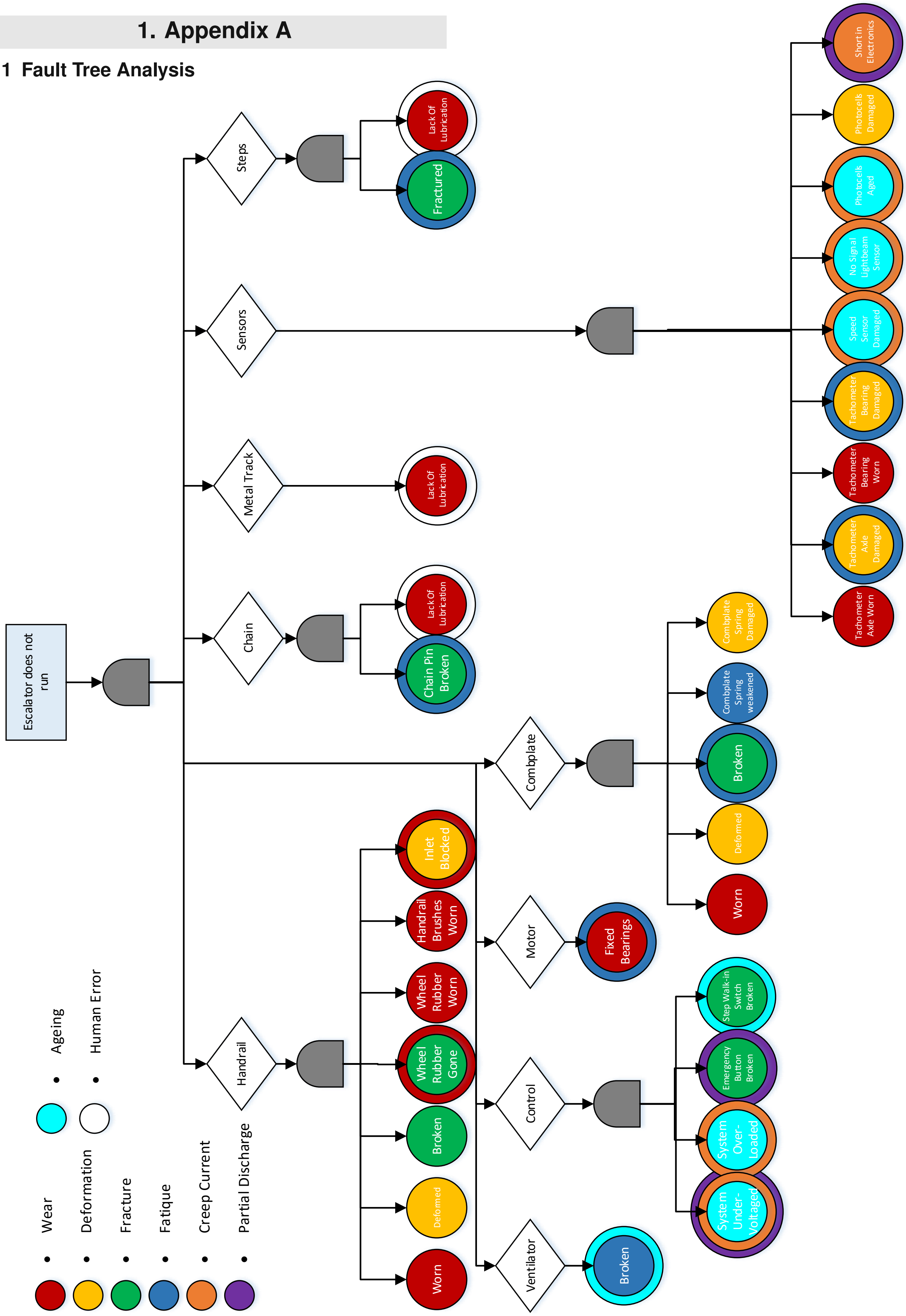
[8] Danfoss. Algemene Wisselstroomtheorie, 2002.

[9] Omron. CX-Drive Operation manual. (November), 2003.

[10] Lutfi R Al-sharif. Lift and Escalator Motor Sizing with Calculations and Examples. *Lift Report*, February(25):1, 1999.

1. Appendix A

A.1 Fault Tree Analysis



2. Appendix B

B.1 Maintenance Modules

Module K
Module Ketting

1. Kettingen moeten gesmeerd zijn maar niet overdadig (zie smeringstabel).
2. Vulcalonbanen moeten elke twee maanden gesmeerd worden.
3. Smeringsvrije kettingen mogen niet direct gesmeerd worden (herkenbaar aan de SF markering zijkant kettingschalmen).
4. Tredekettingen mogen geen gierende of rommelende geluiden maken.
5. Controleer de juiste voorspanning van de kettingen.
6. Visuele controle op te ruime spelling in het geleidingssysteem.
7. Afhankelijk van het kettingontwerp moeten, waar nodig, vulringen zijn toegepast.
8. De rollen mogen geen beschadigingen vertonen.
9. Tredeverbindingen moeten gesmeerd worden maar niet overdadig (waar van toepassing).
10. Kettingspanning: De afstand van twee opeenvolgende treden mag niet groter zijn dan 6 mm.
11. Tredekettingspanning moet correct zijn afgesteld (zie onderhoudsinstructies).
    Het spanstation moet gangbaar zijn.

Module V
Module Aandrijving

1. Er mag geen gierend of rommelend geluid komen uit de lagers van de motor of de overbrenging. De installatie moet gelijkmatig en vrijwel geluidloos lopen tijdens gebruik.
2. De motor en de overbrengingsbehuizing mogen geen olielekkage of vuil vertonen.
3. Alle lagers moeten voldoende gesmeerd zijn.
4. Markeringen voor handmatig tornen moeten duidlijk zichtbaar en leesbaar zijn (indien toegepast).
5. Alle elektrische aansluitingen moeten goed vast zitten en geisoleerd zijn (lasdozen en aansluitkasten).
6. Onderdelen en bedradingen moeten goed bevestigd zijn, vrij van bewegende delen zoals leuningbandaandrijving, ketting, leuningband en tredeaandrijving.
7. De luchtinlaat van de motor mag niet geblokkeerd zijn door stof en vuil (indien toegepast).
8. Visuele inspectie van alle boutbevestingingen van de aandrijving.
9. Alle afschermingen moeten aanwezig zijn, vastzitten en mogen geen bewegende delen raken (indien toegepast).
10. Kettingwieltanden mogen geen haakvormige slijtage vertonen.
11. Motorafdekplaat moet op de juiste manier zijn aangebracht (indien toegepast).
12. Alle dempingselementen van het kettingwiel moeten aanwezig zijn en in goede conditie verkeren, zonder slijtagesporen.
13. Borgmoeren op spanbouten moeten aanwezig zijn en vastzitten.
14. Speling tussen motor en overbrenging.
15. De kettingbreukbeveiliging moet mechanisch en elektrische functioneren en de machine tot stilstand brengen en houden.
16. De tredeomkeerbeveiliging moet voorkomen dat de machine van draairichting verandert.
17. Het ontluchtingsfilter moet vrij van vuil en doorlaatbaar zijn.
18. Het oliepeil moet volgens specificatie van de leverancier zijn.
19. De frictieband van de leuningbandaandrijving moet in goede conditie zijn. Een minimale dikte van 3 mm over de gehele omtrek.
20. Geen zichtbare olielekkage op de pakkingen.

Module G
Module Tredegeleidingssysteem

1. Het vervoer moet soepel en vrijwel geluidloos verlopen over de gehele lengte van de tredeband. Let vooral op de bochten.
2. Vulcalonbanen moeten elke twee maanden gesmeerd worden.
3. De kettingbanen moet schoon zijn aan de binnenkant (neusprofiel).
4. De tredeverlagingsbeveiliging moet mechanisch en elektrisch goed functioneren en de installatie tot stilstand brengen en houden.
5. De tredenwielenbanen moeten schoon zijn.
6. De kettingbanen mogen geen sporen van bovenmatige slijtage vertonen. Let vooral op de bochten. Hiertoe behoren ook de glijblokken, nokprofielen en inloopvorken.
7. Inloopgeleidingen mogen geen bovenmatige slijtage vertonen.
8. De gehele breedte van de trederol of paletrol moet de geleiding raken.
9. De speling tussen de binnenkant van het neusprofiel en de kettingrollen moet behouden blijven.
10. Alle verwarmingselementen moeten functioneren (indien toegepast) als de thermostaat schakelt. De juiste temperatuurwaarde moet ingesteld zijn.
11. De aansluitingen van de verlichtingstransformatoren mogen geen tekenen van oververhitting of corrosie vertonen en moeten goed vastzitten. De afsluiting van de transformatorbehuizing moet goed functioneren (indien toegepast).
12. Bevestigingen moeten goed aangedraaid zijn en alle tussenringen moeten aanwezig zijn.

Module H
Module Leuningbanden

1. Leuningbanden moet ongeveer even snel lopen als de tredebanden. Afwijking tot 2% toelaatbaar.
2. Zorg dat er zomin mogelijk stof ligt.
3. Leuningbandgeleiders moeten uitgelijnd zijn met aaneengesloten naden.
4. Leuningbanden moeten de juiste voorspanning hebben.
5. Leuningbandgeleiders mogen geen tekenen van bovenmatige slijtage vertonen. Let extra op de onderkant van de onderste omkering en de loopkant van de bovenste omkering.
6. Alle verbindingen van de leuningbandgeleidingen moet aanwezig zijn en vastzitten.
7. Rollenbogen mogen geen tekenen van vervuiling vertonen. Ze moeten gelijkmatig en vrijwel geluidloos bewegen zonder slip en zonder afvlakkingen.

Module O
Module Kamdrager

1. De trederibben moeten in lijn liggen met de tanden van de kamplaten.
2. Controleer op schrapende geluiden.
3. De kamsegmenten moeten intact zijn en alle tanden moeten aanwezig zijn.
4. De kamplaatstrippen en bijbehorende schroeven moeten aanwezig en onbeschadigd zijn (indien van toepassing).
5. De kamsegmentverbindingen moeten aanwezig zijn en goed vastzitten.
6. Controleer het kantelen en klappen van de treden als deze langs de kamplaten bewegen.
7. Activering van één van de kamplaten moet de machine tot stilstand brengen en houden.
8. Er moet een smalle opening zichtbaar zijn tussen de schakelpennen en de schakelaars.
9. Alle kamplaten moeten de maximale afstand kunnen afleggen zonder de schakelaar dood te drukken. Het kontakt van de schakelaar moet binnen 10mm uitschakelen en de installatie tot stilstand brengen. Laat indien mogelijk de tanden volledig naar voren komen.
10. De zittingen van de kamplaten mogen geen tekenen van vervuiling vertonen.
    Teflontape (indien aangebracht) moet in goede conditie zijn

Module R
Module Rem

1. De rem mag geen tekenen van vervuiling vertonen.
2. De rem moet op de juiste manier werken en de machine tot stilstand brengen en houden, volgens de vereisten van de norm NEN-EN 115 (max. 300mm doorloop leeg neerwaarts).
3. Alle scharnierpunten moeten goed vastzitten en gesmeerd zijn.
4. Er mogen geen tekenen van corrosie aanwezig zijn op essentiele onderdelen van het remsysteem, die het goed functioneren van de rem nadelig zouden kunnen beinvloeden.
5. Alle bevestigingen moeten goed vastzitten.
6. Alle remsystemen moeten vrij zijn van beschadigingen zoals barsten, scheuren en vervormingen. Controleer de veer op veerkracht en beschadigingen.
7. Het remsysteem moet op de juiste wijze functioneren en de rem moet op het juiste moment openen.
8. Alle bedradingen, kabelgoten en leidingen moete zonder beschadigingen zijn en op veilige plaatsen, vrij van bewegende delen bevestigd zijn.
9. Als de rem gelicht is moet de luchtspleet tussen de voeringen en de remtrommel (schijf) overal gelijk zijn.
10. Als de rem gelicht wordt door een elektromagneet mag deze geen zoemend geluid maken
11. De remlichtsensor en de remslijtagesensor moeten goed afgesteld zijn en op de juiste manier functioneren.
12. Als de rem gelicht wordt door een hydraulische systeem mag deze niet lekken. Het peil van de hydraulische olie moet voldoende zijn om de rem correct te laten werken.
13. De remvoering moet tenminste 3 mm dik zijn over het gehele contactvlak.
14. De remtrommel mag geen sporen vertonen van bovenmatige slijtage door de bevestigingsschroeven van de remvoering.

Module P
Module Schoonmaak

1. Bouw voldoende treden uit om in de put de onderdelen van beide bochten van de installatie te kunnen bereiken.
2. Verwijder de vervuilde absorptiekorrels.
3. Het geleidingssysteem, de aandrijving en het omkeerstation mogen geen olievlekken of vervuiling vertonen. Maak schoon.
4. De bodemplaat mag geen olievlekken of vervuiling vertonen. Maak schoon.
5. De dwarsbalken mag geen olievlekken of vervuiling vertonen. Maak schoon.
6. De lekbakjes mogen geen olievlekken of vervuiling vertonen.
7. Alle leuningbandrollen moeten vrij rollen en moeten de leuningband zonder weerstand geleiden.
8. De in de vloer verzonken opleggingen van het vloerluik mogen geen vervuilingen vertonen.
9. De gehele tredeband mag geen beschadigingen vertonen (controleer de boutbevestigingen, rollen, spiegelvlakken en stavlakken).
10. Alle andere onderdelen mogen geen olievlekken of vervuiling vertonen.

Module B
Module Basis buitenzijde

B

DE ONDERKOP EN BOVENKOP:

Controleer de vloerluiken op:

1. Beschadigingen en slijtage (luik, antieslip en/of bekleding).
2. Obstakels in de omgeving van het luik (losse bekleding of antieslip).
3. Aanwezigheid en vastzitten van de vloerluikschroeven.
4. Hijsgaten in goede conditie.
5. Val-struikelgevaar (ongelijk liggen).
6. Teveel speling. Aan alle zijden voldoende ondersteund.

Controleer de leuningbanden op:

7. Teveel stof en/of vervuiling (slijtage stof).
8. Geen vervuiling door verf, kauwgom en/of stickers.
9. Slijtage plekken en/of scheurtjes in de lippen, scheuren bij naden en inzetstukken.
10. De lassen dienen vlak en zonder beschadigingen te zijn.
11. Visuelecontrole op de leuningbandspanning.
12. Leuningbandinloopbeveiligingen controleren.
13. De conditie van de leuningbandinloopborstels.
14. De conditie (gedurende één tredenband omwenteling) boven- en onderkant.
15. Het synchroon bewegen met de tredeband, zonder slip of aanlopen.
16. De soepele geleiding rond en in het midden lopen van de rollenbogen.
17. Het vrij lopen ten opzichte van vingerbeschermings-profielen.
18. Vrijwel geluidloos functioneren van de rollenbogen.

Controleer de sokkels op:

19. Beschadigingen, deuken en schuurplekken op de panelen.
20. De panelen moeten recht zijn uitgelijnd en geen knikken vertonen.
21. Het goed vastzitten zonder uitstekende delen en losse of ontbrekende schroeven.
22. Verse krassen, schuursporen en schade.
23. Controleer de binnendagprofielen:.

Controleer de leuningband- en/of sokkelverlichting (indien aanwezig):

24. Branden alle lampen.
25. Branden de kamplaatverlichtingen.
26. Geen ontbrekende of losse (eind-)kappen.

Controleer de kamplaat op:

27. Kamtandhoogte maximaal 4mm tussen kamtand en trede (meet op twee plaatsen per segment). Controleer op schrapende geluiden.
28. Beschadigde of ontbrekende tanden (Min. 2 plaatsen per segment).
29. Beschadigde, losse of ontbrekende bevestigingen.
30. Zijn alle strippen aanwezig.
31. Foute uitlijnen van de segmenten (met name RTK, RT-LS en RT-HD).

Controleer de treden op:

32. Juiste uitlijning van inloop en uitloop met kamplaat (obstructie).
33. Bovenmatig speling en vreemde geluiden bij het bewegen (schrapen).
34. Controleer de ruimte tussen de treden onderling (aan beiden kanten). Maximaal 6mm tussen de treden.
35. Controleer de spelling tussen de trede en sokkel (controleer de zichtbare tredeband): Maximaal 4 mm aan één kant (7 mm totaal).
36. Vervuiling (olielekkage/vuil).
37. Conditie van de treden.
38. Beschadigde stavlakken (gedurende één volledige tredebandomwenteling).
39. Beschadigde spiegelvlakken (indien zichtbaar, gedurende één volledige tredebandomwenteling).
40. Branden alle lampen van de tredespleetverlichting (indien van toepassing).

Algemene controle:

41. Controleer pictogrammen, afschermingen, afwijzers, vingerbeschermings-profielen.
42. Controleer de afwijzers op vastzitten(indien toegepast).
43. Controleer de glaspanelen (niet te veel ruimte onderling max. 4mm), zijn de panelen schoon, heel en zonder krassen en/of barsten.
44. Controleer de binnenste balustradepanelen: De conditie op schade of loszitten.van de panelen. De conditie van het profiel tussen de balustradepanelen (indien toegepast).
45. Laat de machine stoppen, controleer de remweg.
46. Controleer de sleutelschakelaar in beide richtingen (wees voorzichtig bij het in tegengestelde richting bewegen).
47. De vervoerskwaliteit (ritcomfort). Soepel lopen van de treden (paletten) over de gehele trap.

Module B
Module Basis in de installatie

B

DE ONDERKOP EN BOVENKOP:

Verwijder de vloerluiken aan de putzijde. Plaats deze op een veilige plek.
Zet de schakelkast op de voorgeschreven wijze uit (indien van toepassing

Controleer de inspectiebesturing voor onderhoud (indien toegepast).

1. Visueel op beschadiging, vooral de kabel.
2. Op verwisselbaarheid en functioneren.
3. Breng de connector van de kabel van de inspectiebesturing aan.
4. Controleer of de knoppen van de inspectiebesturing op de juiste manier werken volgens de aangegeven richting (wees voorzichtig met het in tegengestelde richting laten bewegen).

Schakel de hoofdschakelaar uit:

5. Controleer de werking van de hoofd- en de blokkeerschakelaar in de put (indien toegepast). Controleer of het starten wordt voorkomen.
6. Verwijder de omkeerbeveiligingsplaat (waar van toepassing).
7. Controleer de werking van alle bereikbare beveiligingen. Controleer of het starten van de machine hierdoor wordt voorkomen.
8. Controleer de afgestelde speling bij naderingsschakelaars en andere (eind)schakelaars (indien mogelijk).
9. Controleer de conditie van de inloop van de leuningband of er geen beschadigingen zijn. Maak de inloop en de borstels schoon.
10. Controleer de borstelhouder van de sokkel (indien toegepast): Borstel en houder moeten intact zijn en goed vastzitten. Alle eindkappen moeten goed vast zitten.
11. Controleer de werking van de noodstop. De machine moet tot stilstand komen bij bediening.
12. Controleer conditie van de bedrading en de draadboom (besturingskast/motoraansluitingen) (waar toegepast).
13. Reinig de in de vloer verzonken opleggingen van de vloerluiken. Verwijder alle vuil en stof.
14. Maak het bereikbare deel van de put schoon. Verwijder alle vuil en stof.
15. Reinig olielekkage en vervang absortiekorrels.

Controleer de besturingskast(indien toegepast):

16. De werking van het deurslot van de kast.
17. De bedrading en componenten in de kast op zichtbare gebreken.
18. De opgeslagen foutmeldingen(indien mogelijk).
19. Noteer de stand van de bedrijfsurenteller op het onderhoudsformulier.
20. Controleer de werking van de indicatiepaneel op het binnendagprofiel.

Schakel de hoofdschakelaar in:

21. Laat tredenband in de looprichting bewegen, controleer en luister naar het inkomen van de magneetschakelaars.
22. Laat de tredenband tegen de looprichting in bewegen, controleer en luister naar het inkomen van de magneet-schakelaars.
23. Laat de machine met de inspectiebesturing in de looprichting bewegen: controleer of alle kettingrollen aanwezig en in goede conditie zijn.

Controleer de aandrijfmachine (indien van toepassing):

24. De afstelling van de rem en de status van de remvoeringen.
25. De tomirichting onbeschadigd is en goed vast zit.
26. De motorkoppeling en de aandrijfrubbers in orde zijn.
27. Richtingpijlen voor tomen goed zichtbaar.
28. Oliepeil van de overbrenging.
29. Tachodynamokoppeling functioneert en in goede conditie is.
30. Rubbers van de remmotor in tact en goed vast zitten.
31. De voorspanning van de aandrijfketting.
32. Controleer de kettingen waar zichtbaar, voldoende en juist gesmeerd (zie smeringtabel).

Wees bij ieder bezoek een ambassadeur van KONE BV Liften en Roltrappen

Aankomst:

1 Melden bij contactpersoon en naar bijzonderheden informeren.
2 Afsluithekjes plaatsen.
3 Controleer het ritcomfort.
4 Controleer de verlichting.

Vertrek:

5 Onderhoudskaart, roltrapboek en kaart materiaalvervanging invullen.
6 Schakel de machinekamer verlichting uit.
7 Afsluithekjes opbergen.
8 Afmelden bij de contactpersoon door middel van afsluitend gesprek.

Onderhoudskaart roltrappen, hellingbanen en rolpaden

KONE

Equipmentnr.:
Adres:
Plaats:
Contactpers.: Tel.nr.:

Jaar: Naam monteur	beurt	B	K	V	G	H	O	R	P
	1								
	2								
	3								
	4								
	5								
	6								
	7								
	8								
	9								
	10								
	11								
	12								

Jaar: Naam monteur	beurt	B	K	V	G	H	O	R	P
	1								
	2								
	3								
	4								
	5								
	6								
	7								
	8								
	9								
	10								
	11								
	12								

Jaar: Naam monteur	beurt	B	K	V	G	H	O	R	P
	1								
	2								
	3								
	4								
	5								
	6								
	7								
	8								
	9								
	10								
	11								
	12								

Jaar: Naam monteur	beurt	B	K	V	G	H	O	R	P
	1								
	2								
	3								
	4								
	5								
	6								
	7								
	8								
	9								
	10								
	11								
	12								