

# Dual Rated Speeds Escalator in Rapid Transit System with Extended Ramping Up and Down

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**Keywords:** Dual rated speeds, automatic switching, rapid transit system, acceleration, ramping up, ramping down, vibration, jerkiness.

**Abstract.** To cater for different needs of escalator operating speeds in rapid transit systems (i.e. higher rated speed of 0.75m/s during peak hours is for effective discharging of passengers while slower rated speed of 0.50m/s during off-peak hours is for elderly passengers), we have introduced the dual rated speed escalator. Conventionally, the switching between 2 rated speeds can be done either manually through a key switch or automatically when no passengers are detected on the escalators at pre-set timing. However, there is a possibility of not being able to change speed if there are constant passengers coming into the rapid transit station, taking the escalators. Therefore, this shortcoming will be overcome by setting up a schedule timetable to do the safe switching of escalator rated speeds with passengers riding on the escalators with extended ramping up and down without comprising any safety requirements.

This paper presents the case studies conducted on an existing station where a performance-based approach was adopted. The timing for the speed ramping up/down between the 2 rated speeds has been increased to 30 seconds in order to reduce the acceleration which results in minimizing the acceleration (vibration) and the rate of change of this acceleration (jerk). The objective is to ensure that the passenger's perception are imperceptible and do not experience any abnormal and sudden change of vibration and jerk during the switching of dual rated speeds with extended ramping up and down.

## 1 INTRODUCTION

Rapid transit system (RTS) is the main mode of public transport in Singapore. The escalators at RTS stations are usually heavily utilized to bring in and discharge large amounts of passengers efficiently and safely. Currently, all escalators are designed and operated at the rated speed of 0.75m/s to meet the high travel demands during the morning and evening peak hours.

In recent years, due to the ageing population in Singapore, statistics have revealed that the increase in escalator incidents in RTS stations are associated with elderly passengers due to their increased reaction time and poor understanding of the proper usage of escalators. Surveys conducted have also shown that elderly passengers are more comfortable with slower speed escalators. In order to accommodate the elderly passengers during off-peak hours while the high throughput (primary rated speed of 0.75m/s) is not required, a secondary rated speed of 0.5m/s is incorporated to operate the escalators during off-peak hours.

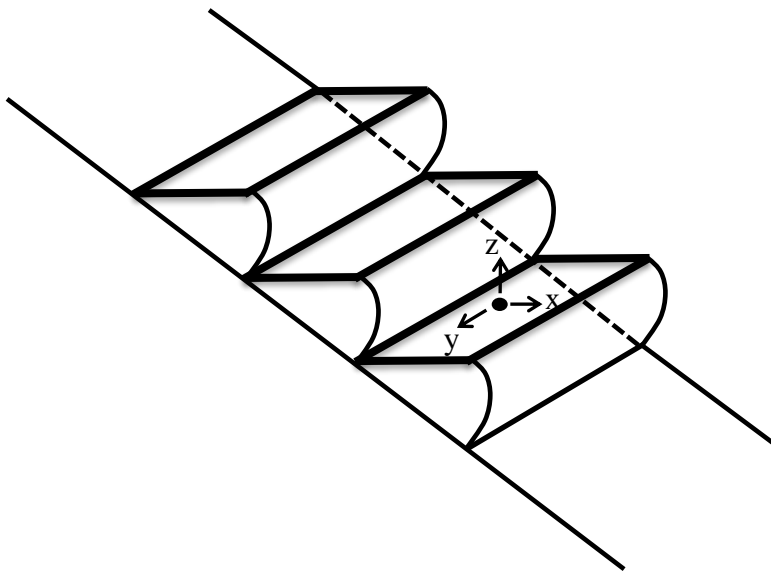
Conventionally, switching between two rated speeds can be done either manually through a key switch or automatically when no passengers are detected on the escalator at pre-set timings. By leveraging on new technology, smooth and gradual acceleration and deceleration of escalators are achievable with more precise digital control for the safe automatic switching of speeds while passengers are still riding on the escalators.

The purpose of this paper is to present the concept and philosophy behind the approach and share the implementation, technical challenges and results for the development of the first in the world

automatic seamless switching between primary and secondary rated speeds with passenger riding on the escalator based on a scheduled timetable.

## 2 CONCEPT AND PHILOSOPHY

The objective of the case studies is to quantify the measure of passenger's perception on the effect of the escalator step acceleration (measured as vibration) in the forward horizontal direction (x-axis) and the rate of change of this acceleration (measured as jerk) [1] for the stability of the passengers on the escalator. An accelerometer is utilized to measure the passenger comfort during the escalator ride in accordance to ISO 18738-2 [2]. Following studies in this paper focus mainly on the x-axis as this is the domineering axis for vibration and jerk whereas the escalator step vibration and jerk along the y-axis and z-axis are well restricted by the escalator step chain, step track and up-lifting tracks.

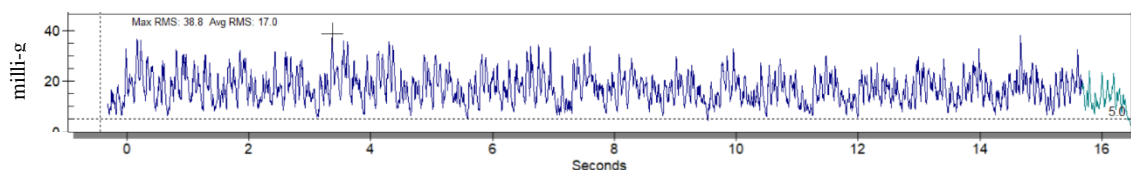


**Figure 1 The 3-axis of acceleration for the escalator step**

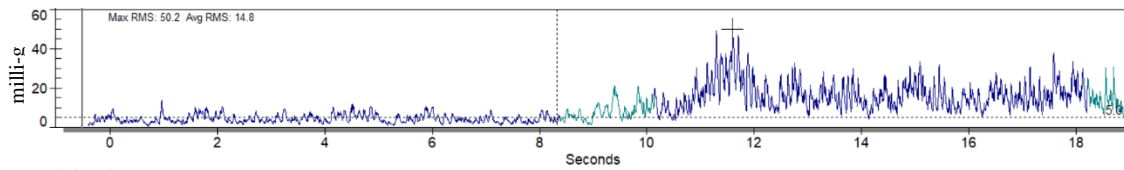
In accordance to SS626 [3] and EN 115-1 [4], escalators or moving walks which start or accelerate automatically by the entering of a passenger shall move with at least 0.2 times the nominal speed and then accelerate less than  $0.5 \text{ m/s}^2$ .

### 2.1 Case study on speed ramping up by 3 seconds – Typical case from the standby speed of 0.2m/s (when no one is using escalator) to the rated speed of 0.75m/s

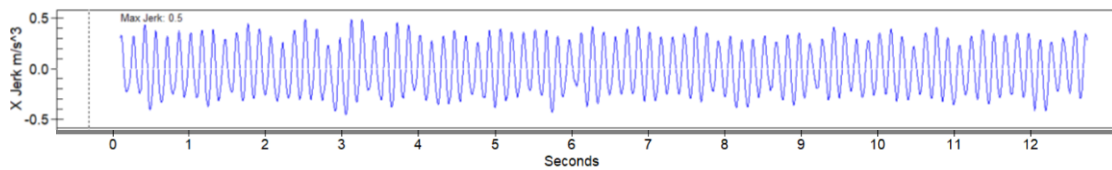
An experiment was conducted on an escalator compliant to SS626 and EN 115-1, where measurements were taken at a rated speed of 0.75m/s as well as the measurements for the escalator speed ramping up from 0.2 m/s to 0.75m/s (within 3 seconds) with an acceleration of  $0.18 \text{ m/s}^2$ .



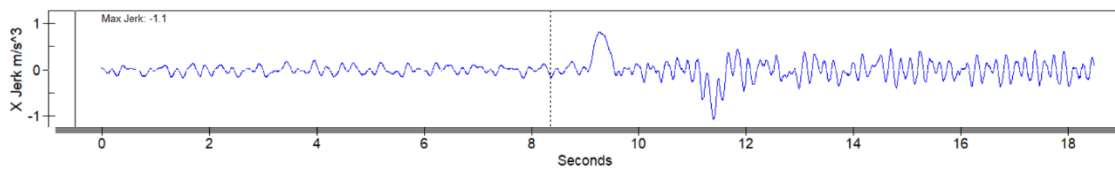
**Figure 2 Vibration of escalator step in the x-axis – speed of 0.75m/s**



**Figure 3** Vibration of escalator step in the x-axis – ramping up from 0.2 m/s to 0.75m/s in 3 seconds (from 9 to 12s)



**Figure 4:** Jerk of escalator step in the x-axis – speed of 0.75 m/s



**Figure 5** Jerk of escalator step in the x-axis – ramping up from 0.2m/s to 0.75 m/s in 3 seconds (from 9 to 12s)

**Table 1** Comparison of Average RMS (Vibration) and Jerk for the speed of 0.75m/s and the ramping up from 0.2 to 0.75m/s in 3s

	Average RMS (milli-g)	Maximum Jerk (m/s <sup>3</sup> )
Speed of 0.75 m/s	17.0	0.5
Ramping up from 0.2 m/s to 0.75 m/s	14.8	1.1

From the above readings, the average RMS value, measuring vibration of the escalator step in the x-axis of the ramping up (3s) is slightly lower than the constant speed of 0.75m/s. This is expected as the slower speed at initial stage of ramping tends to have lesser vibration. However, from the jerk graph, it has showed that there is a maximum jerk of 1.1 m/s<sup>3</sup> as compared to 0.5 m/s<sup>3</sup>. The maximum jerk (rate of change of vibration) of 1.1 m/s<sup>3</sup> occurs when the speed ramping up starts. This implies that although the acceleration value of 0.18 m/s<sup>2</sup> are within the limits stated in SS626 and EN115-1, there is a higher jerk value due to this acceleration within a 3 second timeframe.

As every individual ability to balance would be different due to their physiology and psychology, therefore the increase in the jerk value may cause the passenger to feel uncomfortable or unbalanced [5].

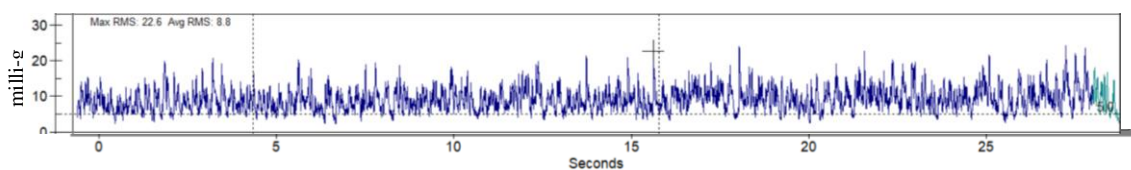
## 2.2 Case study on extended ramping up and down in 30 seconds for dual rated speeds of 0.75m/s and 0.50m/s

The escalator is programmed with a scheduled time table to auto-switching over while passengers are riding on the escalators from a primary speed of 0.75m/s during peak hours to a secondary speed of 0.5m/s during the off peak hours and vice versa.

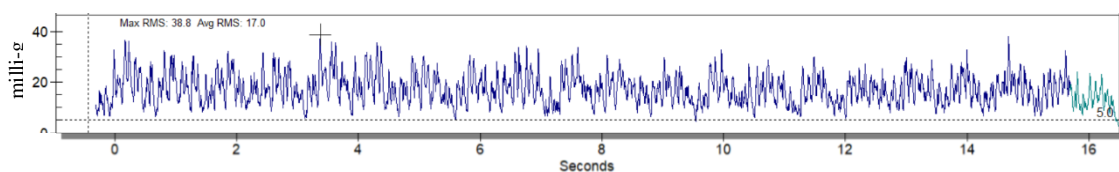
The duration of ramping up and down is set to gradual change between the two rated speeds in 30 seconds. The capability of the variable speed drive is maximized to achieve this function. Theoretically, the acceleration/deceleration of the changeover from 0.5 m/s to 0.75 m/s and vice versa is worked out to be  $0.0083\text{m/s}^2$ . The aim is to ensure the effect (vibration and jerk) during auto-switching over of the escalator rated speeds is imperceptible to passengers while they are riding on the escalator.

The measurements for the same escalator operating at different conditions are carried out:

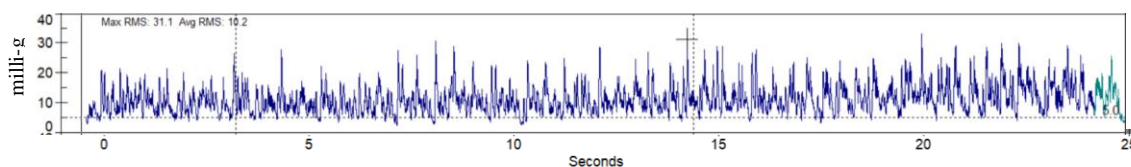
- 1) Escalator rated speed of 0.5 m/s
- 2) Escalator rated speed of 0.75 m/s
- 3) Escalator ramping up speed from 0.5 m/s to 0.75m/s
- 4) Escalator ramping down speed from 0.75 m/s to 0.5 m/s



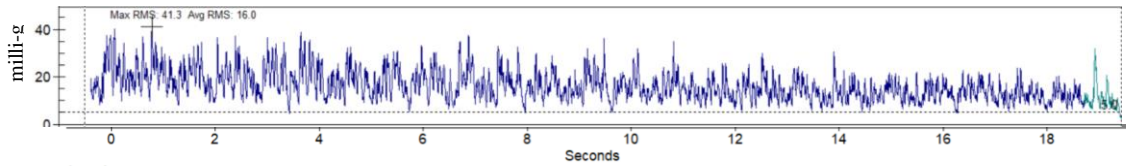
**Figure 6 Vibration of escalator step in the x-axis – speed of 0.50m/s**



**Figure 7 Vibration of escalator step in the x-axis – speed of 0.75m/s**



**Figure 8 Vibration of escalator step in the x-axis – ramping up from 0.5 m/s to 0.75m/s in 30 seconds**

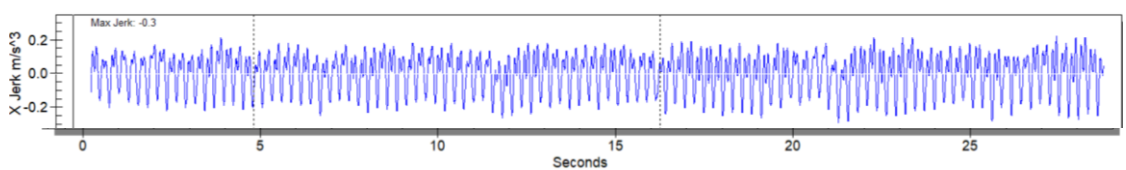


**Figure 9** Vibration of escalator step in the x-axis – ramping down from 0.75 m/s to 0.5m/s in 30 seconds

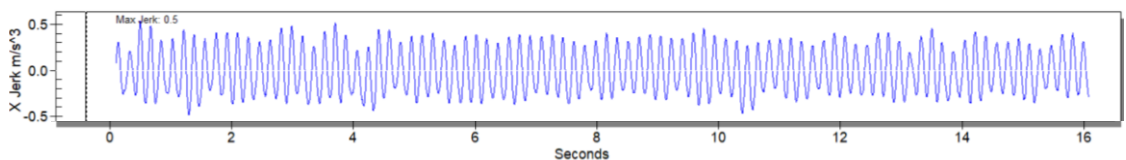
**Table 2** Comparison of Average RMS (Vibration) under various operating conditions

	Average RMS (milli-g)
Speed of 0.5 m/s	8.8
Speed of 0.75 m/s	17.0
Ramping up from 0.5 m/s to 0.75 m/s	10.2
Ramping down from 0.75 m/s to 0.5 m/s	16.0

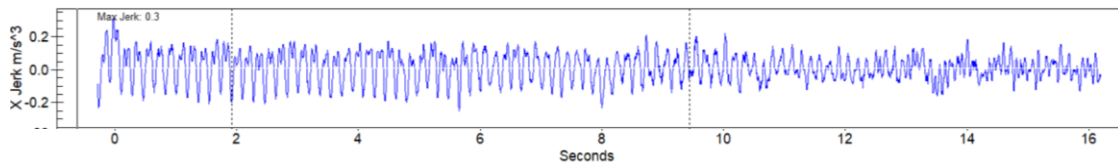
From the vibration of escalator steps in the x-axis under various operating conditions, it was noted that the average RMS values of the step vibration during the escalator ramping up/down are within the limits of the escalator travelling at 0.75 m/s rated speed. There are also no abnormal and large sudden changes of vibration values which could be perceived by the passengers. From the readings, the passenger’s perception during the speed ramping up or down could be similar or less perceptible compared with riding an escalator at a rated speed of 0.75 m/s.



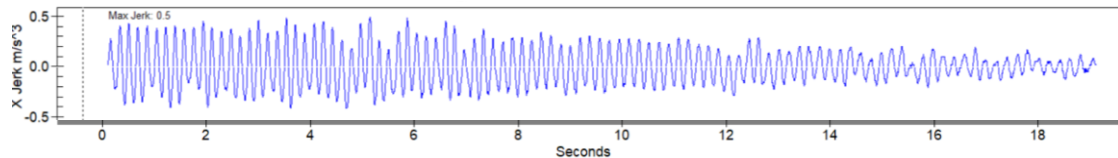
**Figure 10** Jerk of escalator step in the x-axis – speed of 0.5 m/s



**Figure 11** Jerk of escalator step in the x-axis – speed of 0.75 m/s



**Figure 12 Jerk of escalator step in the x-axis - ramping up from 0.5 m/s to 0.75 m/s in 30 seconds**



**Figure 13 Jerk of escalator step in the x-axis - ramping down from 0.75 m/s to 0.5 m/s in 30 seconds**

**Table 3 Comparison of Maximum Jerk under various operating conditions**

	Maximum Jerk (m/s <sup>3</sup> )
Speed of 0.5 m/s	0.3
Speed of 0.75 m/s	0.5
Ramping up from 0.5 m/s to 0.75 m/s	0.3
Ramping down from 0.75 m/s to 0.5 m/s	0.5

The maximum jerk values are compared among various operating conditions. The jerk will have a direct impact on the passenger's ride comfort [6]. For the various escalator operating conditions as indicated in the table, the maximum jerks measured during the extended ramping up and down of the escalator rated speed are also within the limit of the escalator travelling at a rated speed of 0.75 m/s.

From both the graphs of the escalator step vibration and the jerk values, there are also no distinct and large sudden changes in the measured values. Therefore, this shows that the passengers will experience similar or less perceptible vibration and jerk during the ramping up/down in 30s as compared with the ride comfort at the rated speed of 0.75 m/s.

### 3 SAFETY MEASURES

Necessary safety measures are incorporated accordingly to prevent the escalator from overspeed and underspeed and to prevent the sudden change in the acceleration/deceleration which could result in jerkiness of the escalator.

The safety measures are incorporated as follows:

- a) To set the overspeed limit at 0.85m/s, both machine brake and emergency brake will be activated
- b) To set the underspeed limit at 0.11 m/s, both machine brake and emergency brake will be activated
- c) To limit the acceleration/deceleration to  $0.01\text{m/s}^2$ , machine brake will be activated.
- d) Handrail underspeed of -15% will always apply correspondingly to all operating conditions using speed differential between handrail speed and step speed.

#### 4 CONCLUSION

Passenger's ride comfort is subjective. Every passenger's ability to balance under the influence of a forward horizontal acceleration (vibration) and rate of change of the acceleration (jerk) of escalator step differs from one another due to the different physical conditions of each individual.

The purpose of extending the duration of the ramping up/down of escalator speed is to ensure the ramping conditions are gradual & safe while passengers are still riding on an escalator. The case studies of ramping up and down benchmark with the vibration and jerk under the rate speed of 0.75m/s which the current escalator users experienced in RTS of Singapore and was deemed safe. The studies prove that with the extended ramping up and down, the changes are imperceptible to the passengers who do not experience any abnormal and sudden change of vibration and jerk during the switching of dual rated speeds. This proposal of dual rated speed escalator with extended ramping up and down is suitable for a busy RTS environment to accommodate the different needs of escalator operating speeds (i.e. higher rated speed of 0.75m/s during peak hours for effective discharging of passengers and slower rated speed of 0.50m/s during off-peak hours for elderly passengers).

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#### BIOGRAPHICAL DETAILS

Gan Kong Cheong has been in the Lift & Escalator industry for 20 years. He is presently the Principal Project Manager working for Land Transport Authority of Singapore. He has taken part in the design, installation, testing & commissioning of the a few rapid transit line namely, North East Line, Circle Line, Downtown line and also the present Thomson-East Coast Line which has more than 1200 escalators and 400 lifts. He is a Professional Engineer (Mechanical), Specialist Professional Engineer (Lift & Escalator), Specialist Professional Engineer (Access Platform), Authorised Examiner (Lifting Equipment) and Chartered Railway Engineer (S'pore).

Cai Linfan is a certified Chartered Railway Engineer (S'pore) and Professional Engineer in Singapore. He has over 8 years of experience in design, supervision and project management of building services for road and railway transit projects including escalator, elevator, fire protection system and plumbing & sanitary system in Thomson East Coast Line, Downtown Line, North-South East-West Line, Sentosa Gateway Tunnel, islandwide pedestrian overhead bridges and underpasses.

Cheah Sek Cheong is the Principal Project Manager at the Land Transport Authority of Singapore. He has over 35 years of experience in Lifts & Escalators and has oversees various rapid transit projects like the Woodlands line, North East line, Circle Line, Downtown Line and Thomson East Coast Line. He is a Professional Engineer (Mechanical) and Chartered Railway Engineer (S'pore).

Hadi WIJAYA, is the Deputy Director at the Land Transport Authority of Singapore. He has more than 18 years of experience in design of AC High Voltage and Low Voltage system and DC traction power supply system for land transport infrastructure in Singapore. He graduated from Nanyang Technological University with an honours degree in Bachelor of Engineering in Electrical in 1995. He is a Registered Licence Electrical Engineer, Registered Professional Engineer (Electrical) and Chartered Engineer (Railway Engineering) in Singapore.

Melvyn Thong has over 27 years of experience in design, supervision and project management of electrical and mechanical installation for power plants, industrial, commercial and institutional, road and railway transit projects. Over 18 years of experience in the design, supervision and project management of 22kV AC, 400V AC and 750V DC electrical system for Singapore Road and Rapid Transit Systems. Experienced in the design development, implementation and asset renewal of power supply systems for Thomson East Coast Line (TEL), Downtown Line (DTL), Compass Line (NSEW Line), North East Line (NEL), Circle Line (CCL), Sengkang Punggol LRT (SPLRT), Bukit Panjang LRT (BPLRT).

Experienced in high voltage and low voltage reticulation design and is licensed to perform switching in Singapore and has extensive experience in the design and implementation of Mechanical and Electrical Services requirements for Roads and Rapid Transit Systems for RTS and LRT networks. A certified Chartered Electrical Engineer (UK), Chartered Railway Engineer (S'pore) and Professional Engineer in Singapore with a Licensed Electrical Engineering for up to 22kV.