Airport Escalators and Moving Walkways—Cost-Savings and Energy Reduction Technologies

DETAILS

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AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP REPORT 117

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AIRPORT COOPERATIVE RESEARCH PROGRAM

Airports are vital national resources. They serve a key role in transportation of people and goods and in regional, national, and international commerce. They are where the nation's aviation system connects with other modes of transportation and where federal responsibility for managing and regulating air traffic operations intersects with the role of state and local governments that own and operate most airports. Research is necessary to solve common operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the airport industry. The Airport Cooperative Research Program (ACRP) serves as one of the principal means by which the airport industry can develop innovative near-term solutions to meet demands placed on it.

The need for ACRP was identified in *TRB Special Report 272: Airport Research Needs: Cooperative Solutions* in 2003, based on a study sponsored by the Federal Aviation Administration (FAA). The ACRP carries out applied research on problems that are shared by airport operating agencies and are not being adequately addressed by existing federal research programs. It is modeled after the successful National Cooperative Highway Research Program and Transit Cooperative Research Program. The ACRP undertakes research and other technical activities in a variety of airport subject areas, including design, construction, maintenance, operations, safety, security, policy, planning, human resources, and administration. The ACRP provides a forum where airport operators can cooperatively address common operational problems.

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Primary emphasis is placed on disseminating ACRP results to the intended end-users of the research: airport operating agencies, service providers, and suppliers. The ACRP produces a series of research reports for use by airport operators, local agencies, the FAA, and other interested parties, and industry associations may arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by airport-industry practitioners.

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The members of the technical panel selected to monitor this project and to review this report were chosen for their special competencies and with regard for appropriate balance. The report was reviewed by the technical panel and accepted for publication according to procedures established and overseen by the Transportation Research Board and approved by the Governing Board of the National Research Council.

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FOREWORD

By Joseph D. Navarrete
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ACRP Report 117: Airport Escalators and Moving Walkways—Cost-Savings and Energy Reduction Technologies provides a systematic approach to identifying, evaluating, and selecting cost-saving and energy reduction technologies that can be applied to airport escalators and moving walkways. The guidebook and accompanying financial tool provided on CRP-CD-156 can be used to help airports reduce energy consumption and operational costs, improve reliability and customer service, and meet environmental stewardship goals.

Many airports with multiple floors and long walking distances use escalators and moving walkways to improve customer experience. However, not only do these devices have high initial capital costs, they also often have considerable maintenance and energy costs. New technologies (e.g., speed control/variable frequency drive, regenerative braking, and power factor control) can result in cost savings and reduced energy consumption, and recent code changes allowing for variation of escalator and moving walkway speed have expanded the number of available options. Yet many airports do not have the expertise to determine how to apply these new technologies to their unique needs, operations, and site conditions. Research was needed to help airports identify, evaluate, and select the most appropriate cost-saving and energy reduction technologies for escalators and moving walkways.

The research team, led by Project Performance Company/Cadmus, first collected detailed information on available technologies, including their implementation costs and benefits. They then evaluated these technologies with respect to their use at airports. Next the research team interviewed representatives from 46 airports to identify the factors airports use when considering energy-saving technologies; the interviews were also used to receive feedback on the contractor's approach for the guidebook and tool and to confirm which technologies should be included in the research. Based on their findings, the research team developed a guidebook and financial tool that airport practitioners can use to make informed decisions on whether or not to invest in an energy-saving technology for their escalators and moving walkways.

The guidebook provides reasons for improving escalator and moving walkway efficiency, reviews applicable codes and standards, and describes various technologies including LED lighting, capacitors, high-efficiency motors, motor efficiency controllers, and intermittent drives. The guidebook also provides a step-by-step process for selecting, implementing, and evaluating the performance of energy-saving technologies. Lastly, the guidebook offers no-cost and low-cost suggestions for reducing the energy consumption of escalators and moving walkways.

The accompanying financial tool (included with the guidebook as CRP-CD-156 and available for download from the TRB website) is a spreadsheet-based model that airport practitioners can use to help decide which technologies may be appropriate for their escalators and moving walkways given their facilities' unique characteristics (e.g., unit age, operating speed, and amount of pedestrian traffic by time of day). Based on user input, the tool provides a summary of potential energy savings and financial considerations for each technology.

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Note: Photographs, figures, and tables in this report may have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

CHAPTER 1

Introduction

Airports provide an attractive opportunity to reduce energy consumption through energy optimization in escalator and moving walkway systems. The magnitude of potential savings is driven by specific operating requirements that are unique to airports, such as a large number of escalators and moving walkway systems, a large number of passengers passing through on a daily basis, long duty cycles, and increasing stakeholder pressures to adopt sustainable practices in public transport systems. Escalator and motor manufacturers offer multiple energy saving technologies for escalators and moving walkways; however, guidance on which technologies are best for each application is not readily available. The goal of this report and the accompanying financial tool is to provide a resource to help airport managers identify the right energy saving technology for a given airport and estimate the potential savings that would result from the installation of an energy saving technology.

Scope and Purpose

This report is meant to act as a resource to airport managers when selecting energy saving technologies. Its purpose is to (1) provide an overview of the energy saving technologies available on the market today specific to escalators and moving walkways; (2) provide an estimation of the potential savings that would result from the installation of said technologies; and (3) provide guidance on how to select and implement an energy saving technology. In addition to an overview of each technology, benefits and limitations of each technology are discussed.

This project only considered technologies offered for escalators and moving walkways. Energy saving opportunities also exist for elevators and trains; however, an analysis of the technologies available for elevators and trains was outside the scope of this project.

Additionally, an analysis of the safety considerations for each technology was not part of the scope of this project. Although examples of installations of each technology listed can be found within the United States, not all state safety codes allow the use of each technology. All airports are encouraged to perform a safety analysis before the installation of a new technology on their escalators or moving walkway systems.

Finally, the scope of this project only encompasses technologies for installation on an escalator or walkway system. Maintenance operations, which may provide additional opportunities for savings, were not independently reviewed and researched as part of this study.

How to Use this Report

This report contains the following four main sections:

1. Industry background,
2. Energy saving approaches,
3. Guidance on how to select and verify energy saving technologies, and
4. Guidance on how to use the financial evaluation tool.

The Chapter 2, Background, provides an overview of the potential energy savings within the United States that could be achieved by reducing the energy use of escalators and moving walkways. This chapter also provides an overview of innovative technologies currently used in Europe and China. In addition, an overview of the standard that affects the applicability of the technologies included in this report is discussed. Readers are encouraged to review ANSI/ASME A17.1, "Safety Code for Elevators and Escalators" prior to installing an energy saving technology on escalators or moving walkway systems within their airport to ensure the technology meets state requirements.

Chapter 3, Energy Saving Technologies, is split into two parts. The first discusses technologies included in the financial tool that accompanies this report. An overview of the technologies, benefits, and limitations of the technologies is included in this section. Readers are encouraged to review each technology in this section and perform an analysis on the potential savings for their site-specific parameters using the accompanying financial tool prior to selecting the best project for an airport.

The second portion of Chapter 3 discusses technologies that may be recommended by outside sources as viable energy saving technologies, but are either not recommended due to the results of this study or not included in the financial evaluation tool due to the limited data available. Readers are encouraged to review this section as it may provide valuable information regarding technologies that may have been recommended to them in the past.

Chapters 4 and 5 of the report provide guidance on how to select and implement an energy saving technology on a moving walkway or escalator system and how and when to use the financial tool. These chapters act as guides for implementing energy saving projects on an escalator or moving walkway. In addition, the recommendations given in these sections may apply to other energy saving projects, aside from moving walkway and escalator-related installations.

Finally, although maintenance best practices for escalators and moving walkways were not included within the scope of this project, a brief discussion based on the findings discovered while investigating the energy saving technologies is provided in Chapter 6, Best Practices.

CHAPTER 2

Background

Escalators and moving walkways can account for 3 to 5 percent of electric energy use in airports.[1] Components impacting energy use primarily consist of motors, controls, and lighting. Escalators and walkways consume energy based on the run time and the number of people utilizing them at a given time, which makes determining energy savings opportunities unique to each installation.

The opportunity at each airport for energy efficiency improvement for its escalators and walkways depends on the current installation and the available energy saving technologies. Older escalators and walkways tend to be less energy efficient; newer models often already have many of the latest available energy savings technologies. The varied technologies and corresponding case-specific applications can be confusing. This report and the accompanying financial tool are meant to help eliminate confusion by providing a consolidated resource for airport managers.

Escalators and moving walkways are often installed in pairs with one up and one down escalator or two moving walkways moving in different directions. Escalators and moving walkways are both usually driven by electric motors connected to steps in the moving walkway or escalator via a belt or chain mechanism. The size of the electric motor will depend on the load expected but is typically between 10 and 20 horsepower. The handrail is also usually connected to the electric motor via chain or belt. The overhead lighting for a unit is usually not built into the escalator or moving walkway. However, an escalator may have internal lights along the handrail and at the top and bottom to accent the escalator. If a new escalator or moving walkway has internal lights, they are usually light emitting diodes (LEDs). Old escalators and moving walkways typically use four-foot T8 fluorescent lamps.

Applicable Standards

United States safety regulations for escalators and moving walkways are located in ANSI/ASME A17.1, "Safety Code for Elevators and Escalators." The latest revisions to this document at the time of this report are dated as of 2010. Prior to 2010, ASME A17.1 standard, Section 6.1.4.1 prohibited the use of intermittent escalators. Specifically, ASME A17.1 prohibited both variations in speed after the start-up of an escalator and the automatic starting or stopping of an escalator. The release of the updated ASME standard, ASME A17.1-2010/CSA B44-10, permits the escalator speed to be changed provided there are no passengers using the escalator. According to the standard, "rigid performance parameters must be provided to minimize any possibility

[1] Sachs, Harvey M., "Opportunities for Elevator Energy Efficiency Improvements," American Council for an Energy-Efficient Economy, April 2005.

Table 2-1. ASME 17.1 escalator and moving walkway requirements.

Variable	Requirements International System of Units (SI)	Requirements English Units
Minimum allowable speed for an escalator or moving walkway, without a variance	0.05 min/s	10 ft/min
Maximum acceleration/deceleration rate	0.3 min/s^2	1.0 ft/s^2
Maximum allowable speed for an escalator or moving walkway	0.5 min/s	100 ft/min

of speed change when passengers are riding the escalator and that the rate of change of speed of the escalator is sufficiently gradual so as not to cause loss of balance should a passenger bypass the detection means, yet sufficiently rapid to attain full speed when an approaching passenger is detected."

As of this report's submission, many states have not adopted the 2010 version of ANSI/ ASME A17.1. However, escalators and moving walkways with variable speeds can be installed pending permission from individual airport governing bodies. The method for obtaining a code variance differs from state to state. Variations also can be obtained to bring the escalator or moving walkway to a complete stop.

Table 2-1 lists key requirements for escalators and moving walkways outlined in the ASME 17.1 2010 code.

Other requirements for escalators or moving walkways with intermittent drives (varying speeds) that are specific to speed variation include the following:

- The minimum speed shall not automatically vary during inspection operation.
- Passenger detection means should be provided at both landings of the escalator such that
  - Detection of any approaching passenger shall cause the escalator to accelerate to, or maintain, the full escalator speed, conforming to the speed and acceleration requirements listed above.
  - Detection of any approaching passenger shall occur sufficiently in advance of boarding to cause the escalator to attain full operating speed before a passenger walking at normal speed (1.35 min/s, 270 ft/min) reaches the comb plate.
  - Passenger detection means shall remain active at the egress landing to detect any passenger approaching against the direction of escalator travel and shall cause the escalator to accelerate to full rated speed and sound an alarm (requirements for the alarm included in the code) at the approaching landing before the passenger reaches the comb plate.
- Automatic deceleration shall not occur following the last passenger detection before a period of time has elapsed that is greater than three times the amount of time necessary to transfer a passenger between landings.
- Means shall be provided to detect failure of passenger detection; means shall cause the escalator to operate at full rated speed only.

Potential Savings in the United States

According to U.S. Representative Louise Slaughter, who, in 2005, proposed escalators and walkways should be allowed to run intermittently, escalators and walkways are used 90 billion times per year in the United States. The amount of energy consumed by their operation is approximately equivalent to powering 375,000 homes and costs $260 million per year.[2]

[2] "New Technologies Provide Options for Making Escalators More Energy Efficient," John Hurst, *Elevator World*, January 2007.

Many energy savings technologies that have been installed in Europe and Asia (e.g., intermittent drives for two-speed operation and start–stop operation) have not yet been installed in the United States in large quantities. Since many states have yet to adopt the latest version of the ANSI/ASME A17.1 Escalator and Walkway Safety Code that allows use of intermittent or start–stop operation, most local building codes do not allow installing equipment that provides intermittent or start–stop operation.

Installing additional technologies such as LED lighting and regenerative drives can result in even greater savings. The actual savings on a given escalator will depend on how often the unit is idle, but a recent European study estimated that installing intermittent drives on all of Europe's escalators could reduce total electricity use by about 28 percent.[3] Energy savings technologies, such as regenerative drives and motor efficiency controllers, are just now gaining popularity in the United States. The energy savings potential for escalators and walkways is estimated to be in the range of 10 to 40 percent per upgraded escalator.[4]

Innovations in Europe and China

According to a 2011 report, Europe is the largest market for escalators and accounts for nearly half of the total installed base of escalators worldwide. However, China currently leads the market as the fastest growing market for escalators.[5]

An amended version of China's Energy Conservation Law became effective on September 1, 2009. As a result of this law, measures regarding high energy-consuming equipment, specifically related to elevators and escalators, were put into effect. In 2009 and 2010, several airport construction projects completed in China took advantage of the latest escalator energy savings advancements. The largest project was the construction of the Hongqiao Airport, which has since become the largest travel hub in the nation. Over 100 escalators with intermittent drives and other new energy technologies were installed at this airport.[6]

European Standard EN115 Safety Rules for the Construction and Installation of Escalators and Passenger Conveyors, governs escalator installations in Europe. The European E4 Project, Energy Efficiency in Buildings, conducted a study on elevators and escalators from 2007 to 2010, concluding that a potential reduction of around 30 percent might be feasible if all of the escalators in Europe were equipped with automatic speed controls and with low power standby modes. The results prompted large-scale installation of these technologies across Europe.

Intermittent or variable-speed escalators were popular in Europe and Asia several years prior to their installation in the United States, primarily due to the national safety code which previously forbid escalators from changing speed, as described previously in this chapter in the section on applicable standards.

[3] "Global Escalator & Elevator Market Report: 2011 Edition Latest Reports by Koncept Analytics," September 2011, http://www.prlog.org/11677776-global-escalator-elevator-market-report-2011-edition-latest-reports-by-koncept-analytics.html
[4] Carlos Patrao, Anibal Almeida, Joao Fong, and Fernando Ferreira, "Elevators and Escalators: Energy Performance Analysis," *Summer Study on Energy Efficiency in Buildings*, *ACEEE* 3 (2010): 3-53–63.
[5] "Global Escalator & Elevator Market Report: 2011 Edition Latest Reports by Koncept Analytics," September 2011, http://www.prlog.org/11677776-global-escalator-elevator-market-report-2011-edition-latest-reports-by-koncept-analytics.html
[6] "Global Escalator & Elevator Market Report: 2011 Edition Latest Reports by Koncept Analytics," September 2011, http://www.prlog.org/11677776-global-escalator-elevator-market-report-2011-edition-latest-reports-by-koncept-analytics.html

CHAPTER 3

Energy Saving Technologies

This chapter provides a discussion of energy saving technologies for escalators and moving walkways. The discussion is divided into two sections that focus on (1) technologies included in the financial tool and recommended for consideration and (2) technologies not included in the financial tool and not recommended for installation.

Various reasons are provided for why the second group of technologies should not be included in the financial tool. Technologies not included in the financial tool may result in low energy savings and, consequently, long payback periods; may no longer be available for installation; or may have limited data available, resulting in difficulty estimating the energy use of the technology.

Technologies Included in the Financial Tool

All technologies in the following section should be considered and evaluated for installation prior to selecting a technology. A brief description of each technology, along with a summary of benefits and limitations, is provided.

This section discusses both stand-alone technologies and technology pairings that are included in the financial tool that accompany this report. The technologies described in the following section include:

- LED lighting,
- Capacitors,
- High-efficiency motors,
- Motor efficiency controllers (MECs),
- Intermittent drives,
- Intermittent dives paired with motor efficiency controllers,
- Intermittent drives utilizing variable voltage–variable frequency drives, and
- Intermittent drives paired with regenerative drives.

LED Lighting

Overview—LED or light emitting diode lighting is a semiconductor light source. It is available for handrail and landing platform lighting for escalators and moving walkways as an upgrade or replacement to the existing fluorescent. They are straightforward replacement/upgrades for existing linear lighting. All manufacturers offer LEDs as an upgrade or with new installations.

LEDs have the advantages of lower energy consumption, extended time between failures, and longer life. The largest disadvantage is cost. While LED pricing has been decreasing over

Figure 3-1. Capacitors.

the years, LED purchase costs are still several times more than fluorescent lamps. Prices vary so shopping around will assist in price control, and decisions should consider life cycle costs.

Benefits—Installing LED lights will result in reduced energy consumption, reduced maintenance downtime, and extended time between failures.

Limitations—LEDs are sensitive to heat; so, operations in hot areas will reduce time between failures. However, this typically will not be an issue for escalators and moving walkways since the movement of the rotating steps and handrail creates adequate air movement.

Capacitors

Overview—In an electrical distribution system, a load with a low power factor[7] draws more current than an equivalent load with a high power factor, resulting in the same amount of useful power. This need for a higher current increases the energy lost in the distribution system, and requires larger wires and other electrical equipment. Due to the costs of larger equipment and wasted energy, utilities may charge a higher cost to customers for a low power factor.

Linear loads with low power factor, such as an unloaded or lightly loaded escalator motor, can achieve greater energy efficiency through the addition of capacitors. Capacitors (see Figure 3-1) used for the correction of a power factor in escalators and moving walkways should be installed as close to the motor as possible to maximize the energy savings. Power factor correction capacitors bring the power factor of an alternating current (AC) circuit closer to 1.0, which is the ideal power factor. It is usually impractical to correct the power factor completely to unity (1.0). There is a diminishing benefit per incremental cost. Adding capacitors will act to cancel the inductive effects of the load, thus reducing the need for reactive current to be generated by the utility and reducing the current flow through the distribution system, and therefore in lower power loss.

[7] Power factor (PF) is a measure of the efficiency use of power, or ratio of working power (kW) to apparent/total power (kVA).

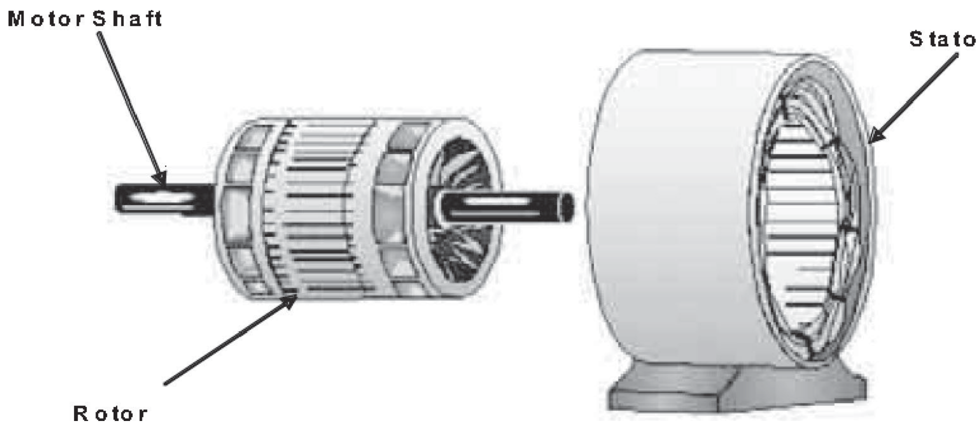


Figure 3-2. Asynchronous squirrel-cage AC induction motor.
Source: Elevator World

Benefits—Installing capacitors can result in reduced electricity costs if the utility rate structure includes penalties for low power factor. A typical payback period is less than 2 years.[8] Capacitors can increase system capacity (e.g., for generators, cables, transformers, etc.), improve voltage regulation, and reduce losses in transformers and cables. Capacitor installation requires minimal capital or labor investment.

Typical distribution system losses are in the range of 1 to 4 percent of total kilowatts used. Capacitors can improve distribution losses by 1.5 to 2 percent on average.[9]

Limitations—Capacitor installations may not result in an acceptable economic payback, even when a facility is being charged kVA billing at a 1.0 power factor target, the most expensive power factor penalty.

Capacitors should not be installed on distribution systems with high harmonics since harmonics can cause capacitors to fail. Harmonics are non-linear current or voltage in an electrical distribution system that increase power system heat losses.[10]

There is the possibility of the distribution system going into a leading power factor situation at light load if passive capacitors are installed. Some utilities charge for a leading power factor. To avoid this, an active switched capacitor bank may be required, which, depending upon complexity, can be cost prohibitive.

High-Efficiency Motors

Overview—The majority, if not all, of the power consumption within an escalator/moving walkway is consumed by its motor. A typical escalator is equipped with a 7.5 to 15 kilowatt (10 to 20 horsepower) inductive AC motor.[11] The most common AC motor seen in escalators is the induction asynchronous squirrel-cage motor (see Figure 3-2), composed of an external stator core and rotating rotor.[12a] The power consumption of a motor is inversely related to the

[8] "Power Quality Solutions and Energy Savings—What Is Real?" Eaton Industry Application 1A02704001E, March 2010, Daniel J. Carnovale and Timothy J. Hronek.
[9] Ibid.
[10] Ibid.
[11] "Overview of a Typical Motor," Power Sines, http://www.powersines.com/SinuMEC_Market_need
[12a] Christine Toledo, "Improving Motor Efficiency in Constant Speed Applications," *Elevator World*, Oct. 2007, http://www.elevator-world.com/files/oct07_copy.pdf

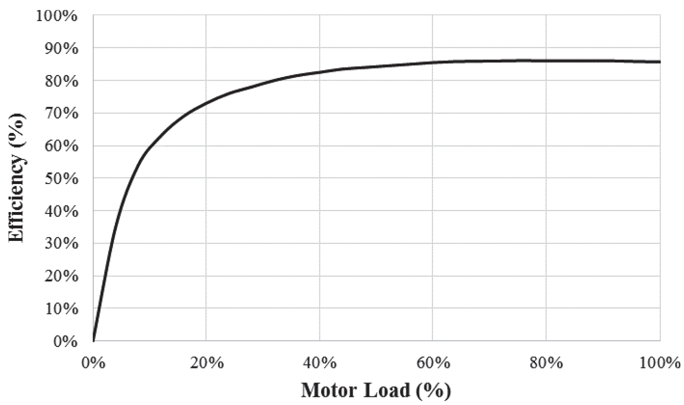


Figure 3-3. Sample efficiency curve for a standard AC induction motor.

efficiency of the motor; therefore, the energy consumption of the escalator or walkway can be greatly reduced by installing a high-efficiency motor (see Figure 3-3).

There are two basic classes of motors, direct current (DC) and alternating current (AC). AC motors are less expensive, more reliable, and more efficient for applications requiring extended periods of use such as escalators or moving walkways. Within the motor class of AC motors, there are two main types: induction and synchronous.

Losses make a motor inefficient. There are five main types of losses in an AC induction motor: stator power losses, rotor power losses, magnetic core losses, friction and windage losses, and stray losses. These losses can be minimized by constructing the motor with superior magnetic materials, larger magnetic circuits with thinner laminations, and larger copper or aluminum cross sections in the stator and rotor windings. High-efficiency motors are usually constructed with these features, and have tighter tolerances, better quality control, and optimized designs. These modifications result in the motors having lower losses, improved efficiency, lower operating temperatures, and improved reliability.

In addition, most motors within escalators are oversized because they are designed for maximum capacity of two people per step. In a typical AC motor, the efficiency peaks when 90 percent loaded, and drops significantly when the load is between 25 percent and 50 percent.[12b] If a motor is oversized, running with a load less than 50 percent, it will not run efficiently and the energy consumption will increase. If the actual required peak load is known, installing a smaller motor to match the load required can also greatly reduce the energy consumption of an escalator or moving walkway. If a smaller motor cannot be installed, a variable voltage–variable frequency drive (VVVF) can be installed to reduce the energy consumption at lower loads. (See this chapter's section on VVVFs for more information.)

A typical standard efficiency induction motor has an efficiency of approximately 84 percent when fully loaded in the size range typically found in escalators and moving walkways. The highest efficiency motors commercially available typically have a nominal efficiency of approximately 90.2 percent in the size range used for escalators and moving walkways.[13] The potential savings from installing a high-efficiency motor depends on the number of operating hours, motor horsepower, and typical load.

[12b] Toledo, Christine. "Improving Motor Efficiency in Constant Speed Applications." *Continuing Education: Motor Efficiency.* Elevator World, Oct. 2007. Web. 30 Apr. 2013. http://www.elevator-world.com/files/oct07_copy.pdf

[13] "Improving Motor and Drive System Performance," US Department of Energy, September 2008, https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/motor.pdf

Benefits—Installing a high-efficiency motor on an escalator or walkway can greatly reduce operating costs. The operating cost of a motor can represent up to 97 to 98 percent of lifetime costs.[14] For small motors that have high operating hours, the payback period for a high-efficiency motor can be as low as 7 months. Typically, as the size of the motor and the operating hours increase, the payback period decreases.

In addition, high-efficiency motors are often more reliable, durable, and quieter than standard efficiency motors.

Limitations—High efficiency motors cost approximately 15 to 25 percent more than standard motors depending on the size, or $8 to $40 more per horsepower.[14] Like all upgrades requiring a component to be replaced, the installation of a high-efficiency motor will require the escalator or walkway to be turned off for a period of time for the installation and will be accompanied by an installation cost, if installed by an outside contractor.

Depending on the motor and system, modifications may need to be made to the drive system or motor controls if a high-efficiency motor is installed. If modifications are required, the installation cost will be higher and the payback period will be lengthened. In addition, high-efficiency motors often have less slip, which can result in a slightly higher rotational speed. Slip is the difference between the rotational speed of the stator and rotor. The change in rotational speed should be considered when contemplating installing high-efficiency motors.

Motor Efficiency Controller

Overview—A motor efficiency controller (MEC) improves the efficiency of a motor during various loading conditions. MECs are solid-state controllers that dynamically optimize the efficiency of 3-phase AC motors. MECs should only be used on 3-phase motors in escalator and walkway applications. Use of MECs with single-phase motors requires replacement of wiring and produces increased line losses, and therefore is not recommended for single-phase motors. Motors typically operate most efficiently when loaded to 75 percent of their maximum capacity. However, escalators and walkways are commonly loaded from 0 percent to 50 percent; as a result, the motors do not run at their most efficient condition. A fully loaded escalator is defined as having two people on each step, a situation that rarely is seen in practice. MECs are designed to address this low loading issue.

As stated previously, the six main losses in an AC motor are: friction, windage, stator power, rotor, magnetic core, and stray losses. The magnetic core loss is the energy lost due to eddy currents and hysteresis effects in the magnetic iron cores of the stator and rotor; it is a function of the voltage of the motor terminals. This loss is independent of the load. A motor operates most efficiently when the motor load is above 75 percent of the fully rated load. When the load is very low, the magnetic core loss dominates, representing most of the energy loss. By lowering the voltage, the MEC reduces the magnetizing current and thus the magnetic losses. This reduces the total power delivered to the motor; and since the power delivered to the load has not changed, the efficiency is increased. In addition, the MEC reduces the magnetizing current, which is the inductive component of the total power and total current, resulting in an increased power factor.

MECs, also known as sinusoidal controllers, modify the shape of the standard AC current wave to reduce voltage and thus improve efficiency and power factor, as shown in Figure 3-4.

[14] Lowe, Golini, Gereffi, "U.S. Adoption of High-Efficiency Motors and Drives: Lessons Learned," Center on Globalization Governance & Competitiveness, February 2010, http://www.cggc.duke.edu/pdfs/CGGC-Motor_and_Drives_Report_Feb_25_2010.pdf

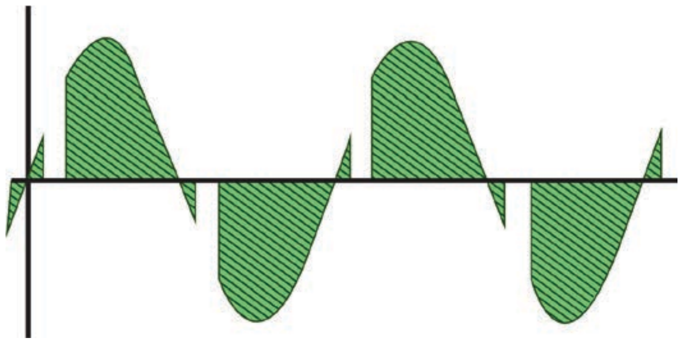


Figure 3-4. Standard AC motor current.

There are several methods used by MEC manufacturers to accomplish this, but the end result remains the same: reduced voltage to improve efficiency and save energy for motors at low load. The method shown here is the Nola Method designed by the National Aeronautics and Space Administration (NASA). The Nola Method is named after its inventor, Frank Nola, an engineer with NASA's Marshall Space Flight Center.

The energy savings as a result of MEC installation will vary based upon the escalator or moving walkway loading, but it is expected to be approximately 10 to 25 percent for lightly loaded escalators. No savings will be achieved if the load factor is above 75 percent, and minor losses will be incurred to the added energy consumed by the MEC.[15]

Benefits—MECs bring other benefits in addition to energy savings. MECs are soft start motor controllers, thereby resulting in energy savings during start-up and when the escalator is actively being slowed. MECs have an option to handle regenerative energy on the down escalator without any additional filters or bypasses. When passengers are being transported on a down escalator, a motor acts like a generator (asynchronous motor) and energy is produced. In a traditional escalator with a control system, this energy is converted into heat using dynamic braking resistors and dissipated as heat. The MEC controls the escalator load under all conditions and sheds excess energy by converting the energy into electricity and adding it safely back into the supply network for use in building lighting or other applications. However, the accompanying financial tool does not account for regenerative savings.

Other potential benefits include reduced operating temperatures of the motor, which in turn reduces maintenance costs and extends motor life (not quantified under this study). In addition, MECs minimize conductive losses in a fashion similar to capacitors.

Limitations—In areas where loading is high, above approximately 75 percent of the full load capacity, there would be little savings when using a motor controller. In addition, motor controllers can cause significant harmonic distortion, which can increase distribution losses and kilowatt usage, as well as damage equipment and reduce motor life.

The motor that the MEC is installed on must be inverter rated. MECs are only compatible with inverter rated motors. If the MEC is programmed to handle regenerative energy, the electrical distribution system must be able to handle regenerative energy and fully protected from short circuits and disturbances.

[15] "MEC vs. VSD," Power Efficiency Corporation, May 2012.

Intermittent Drive

Overview of Technology—An escalator equipped with an intermittent drive allows for two-speed operation. With an intermittent drive, the escalator speed can be reduced to a minimally accepted speed or to a complete stop depending on the variance received by local authorities. Escalators using an intermittent drive slow down or stop when the escalator is not in use and speed up to normal operating speeds when a rider appears. Significant energy is saved by slowing down or stopping the electric motor driving the escalator.

The traditional AC-motor-driven escalator design assumes the worst-case scenario where the escalator is fully loaded with two riders per step. However, escalators usually operate with much fewer riders than a full load, resulting in a partially loaded escalator. This low load results in resistance losses in the stator and in the rotor, miscellaneous stray losses, and a low power factor, impacting efficiency and electricity costs.

An intermittent drive is usually comprised of an inverter and sensor. Typically, a variable frequency drive (VFD), which also is known as an adjustable-speed drive (ASD), is used as the inverter. A VFD regulates the frequency delivered to the motor, which directly affects the speed and rotational force of the motor. By installing an entrance monitoring system and VFD, an escalator can be turned on automatically when the passenger activates the sensor or barrier. If the entrance monitoring system is not activated during a pre-defined time, the escalator slows to an allowable speed or stops completely (see Figure 3-5). When activated, the escalator ramps up to a rate of speed based on configurable acceleration curves. Some escalator manufacturers use motion sensors to detect an approaching passenger; others use light barriers or contact mats. It is important that whatever the detection method used, it is reliable to ensure that the escalator will not change speed while there are passengers on board.

The most recent American Society of Mechanical Engineers (ASME) Code A17.1: *Safety Code for Elevators and Escalators* allows the speed of the escalator or moving walkway to change after start-up. The minimum allowable speed is 10 feet per minute and maximum allowable speed is 100 feet per minute; however, variations have been allowed so the escalator may come to a complete stop. Under this provision, escalators and moving walkways must have a means of passenger detection at both landings of the escalator or walkway; additionally, acceleration and deceleration rates cannot exceed 0.3 m/s^2.

As stated in Chapter 2, in the Applicable Standards section of this report, prior to 2010, the ASME A17.1 code did not allow the use of intermittent drives on escalators or moving walkways. Changes to Sections 6.1.4.1.2 and 6.2.4.1.2 of the code allow for variation of escalator and moving walkway speed after start-up.

Not all states have adopted ASME A17.1-2010/CSA B44-10 yet; however, some states that have not yet accepted the code may make exceptions for installation of intermittent drives on a case-by-case basis.

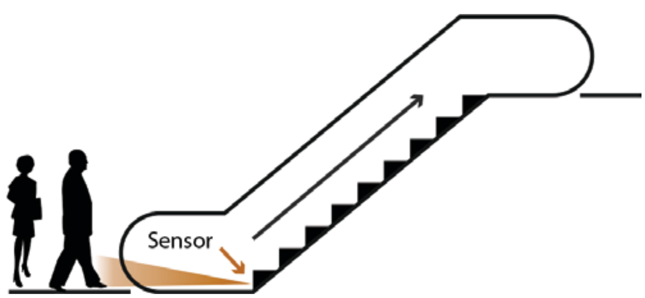


Figure 3-5. Typical automatic speed reduction system.

Benefits—Installing an intermittent drive can result in energy savings of up to 25 percent depending on passenger load.[16] The actual savings on a given escalator or moving walkway will depend on how often the unit is idle, but a recent study done by Portugal's University of Coimbra estimated that installing intermittent drives on an escalator or moving walkway could reduce total electricity use by about 28 percent.

Limitations—The intermittent operation of an escalator has limited applicability. It is not suitable where escalators are in constant use as this leaves little to no intermittent periods to generate reasonable savings. It also is not suitable on systems that do not have inverter-rated motors.

Retrofitting an escalator or moving walkway to run intermittently or replacing it with a new intermittent-run escalator is expensive. According to a 2006 GSA and National Institute of Building Sciences' *Intermittent Escalator Study*, the design, equipment, and construction may cost $15,000 to $30,000 per escalator.[17]

The equipment required for intermittent operation includes a sensor for oncoming passengers and enough space for a corridor (or a gate/turnstile) to prevent passengers from stepping on the escalator before it is up to full speed. In some situations, there is not enough space for the installation, or architectural changes needed to allow the installation are cost prohibitive.

Changing an escalator's speed may increase potential liabilities for escalator manufacturers and property owners, due to the increased potential for passengers to lose balance and fall during acceleration or deceleration.

Intermittent Drive with Motor Efficiency Controller

Overview—By pairing an intermittent drive with a motor efficiency controller, the energy consumption of an escalator is not only decreased by reducing the speed when passengers are not present, but also by reducing the energy consumption when the escalator is running at full speed and carrying passengers. As described in the previous section on motor efficiency controllers (MECs), the MEC dynamically optimizes the efficiency of a 3-phase alternating current (AC) induction motor. A MEC lowers the voltage delivered to a motor when the load is low (e.g., below 50 percent). This reduces the magnetic losses in the motor, which are the most significant losses, and increases the motor's overall efficiency.

The intermittent drive technology is a solid-state control that takes input from sensors to determine if someone is on the escalator. The sensors are located at either end of the escalator/walkway and communicate to the two-speed motor to stop or start the unit. Energy savings in the range of 30 percent to 35 percent can be achieved by both slowing the escalator when not in use and by reducing the energy consumption through voltage reduction when passengers are present.[15]

Benefits—When paired together, an intermittent drive and MEC can result in significantly higher savings. The MEC reduces the energy use during full speed, but low passenger load operation, and the intermittent drive reduces the energy use when passengers are not present.

As stated earlier, MECs have an option to handle regenerative energy on the down escalator without any additional filters or bypasses. In addition to energy and cost savings, chances of motor failure are reduced since the motor operating temperature is lowered by the MEC. By lowering the motor operating temperature, the motor life also will be extended and conductive losses in the electrical line will be reduced.

[16] ISR—University of Coimbra (Portugal), *Energy Efficient Elevators and Escalators.* "*E4.* Intelligent Energy Europe" N.p. Mar. 2010. Web. 30 Apr. 2013.

[17] U.S. GSA and National Institute of Building Sciences, *Intermittent Escalator Study*, 2006, as required by the Energy Policy Act of 2005.

Limitations—An intermittent drive paired with a MEC can result in higher savings than either technology would achieve if installed alone. However, the limitations for both technologies still apply, even when paired together. Retrofitting an escalator to run intermittently or replacing it with a new intermittent-run escalator is expensive. The equipment costs for the sensors and a corridor/gate can be significant. In addition, the motor on the system must be inverter-rated in order for an intermittent drive and MEC to be installed.

ASME's recent changes to Code A17.1 allow the speed of the escalator or moving walkway to change after start-up. However, the code has not yet been adopted in all states. If installation is being considered in a state in which the code has not been adopted, the facility owner may apply for a variance to allow the escalator speed to change despite the lack of code adoption.

Intermittent Drive Utilizing a Variable Voltage–Variable Frequency Drive

Overview—Motor controls such as variable voltage drives, variable frequency drives, and variable voltage–variable frequency drives can result in significant energy savings for escalators and walkways. A variable voltage drive (VVD) increases and decreases the voltage delivered to the motor, directly affecting the energy consumption of the motor. Similarly, a variable frequency drive (VFD) changes the frequency delivered, which directly affects the escalator's speed. Variable voltage–variable frequency (VVVF) drives allow for the control of both the voltage and frequency delivered to the motor.

Figure 3-6 shows a standard configuration for a VVVF drive. The incoming alternating current is converted to a direct current before it enters a filter. The exiting current is then converted to the desired frequency and voltage in a DC/AC inverter before passing to the motor.

The most common VVVF drive is the pulse width modulation (PWM) voltage source inverter. A PWM divides a sinusoidal output wave into a series of narrow voltage pulses by alternating between a positive voltage, no voltage, and negative voltage. The main benefit of using a PWM is that power loss in the switching devices is very low. In addition, with a PWM the lower voltage harmonics can be greatly reduced, resulting in a smooth rotation in the motor and comfortable rides on escalators and walkways.

VVVF drives are often used in conjunction with other technologies to reduce the energy use of an escalator or moving walkway. For example, if paired with a sensor, a VVVF can be used for an intermittent drive system. The sensor will note when the escalator is not in use and drop the voltage and frequency delivered. This, in turn, reduces the speed and energy drawn by the motor. The highest potential savings for a VVVF is seen when it is paired with a sensor to form an intermittent drive. Alone, a VVVF cannot detect a lack of passengers to adjust the speed of the escalator accordingly. When paired with a sensor, a VVVF reduces the energy consumption during start-up and at low speed when passengers are not present. However, no additional savings occur during start–stop operation.

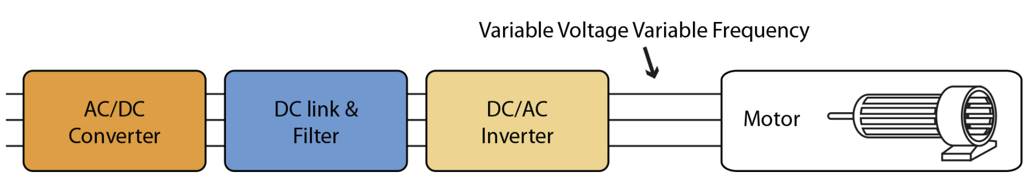


Figure 3-6. General configuration of a VVVF drive.

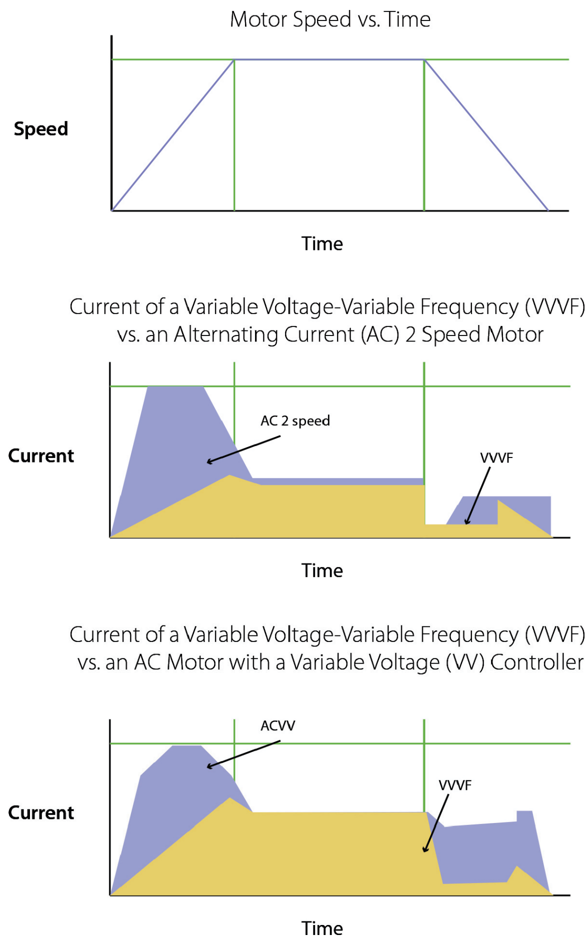


Figure 3-7. Comparison of AC motor, AC motor with VV, and AC motor with VVVF.

Benefits—A VVVF can reduce energy consumption of an escalator by up to 30 percent.[18] In addition, VVVFs can increase the useful life of a motor. According to the *Intermittent Escalator Study*, controlling the speed of a motor can reduce maintenance costs by up to 2 percent per year.[19]

In addition to energy and cost savings, VVVFs allow for the most precise control of escalator speed when compared to other means of control. In the past, it was difficult to precisely control the acceleration and deceleration rates of escalators and moving walkways. However, technology advances over the past 15 years have resulted in the ability to precisely control the speed of AC motors used for escalators and moving walkways. VVVF motor controllers available today provide that control for escalators and moving walkways so that the desired rate of speed change is never exceeded, not even for a fraction of a second.

The VVVF also allows for low starting currents when compared to a two-speed AC motor or an AC motor with a variable voltage controller. Figure 3-7 shows a comparison of the current

[18] "KONE Solutions & BREEAM." *KONE: Dedicated to People Flow.* KONE Great Brittain, n.d. Web. 30 Apr. 2013. http://www.kone.com/countries/en_GB/environment/BREEAM/Pages/default.aspx

[19] U.S. GSA and National Institute of Building Sciences, *Intermittent Escalator Study: As Required by the Energy Policy Act of 2005*, https://fortress.wa.gov/ga/apps/sbcc/File.ashx?cid=719

over time for a two-speed AC motor, an AC motor with a variable voltage controller, and an AC motor with a VVVF. The increase in current for the motor with a VVVF drive is more gradual than the increase for a two-speed motor or a motor with a basic variable voltage controller. This provides a smooth ride for the passengers and a higher power factor. Additionally, the low starting currents help to increase the useful life of the motor serving the escalator or walkway.

Limitations—Variable voltage–variable frequency drives do not work for all applications. As with any escalator technology that automatically changes the speed of an escalator or walkway, the chance of an accident or injury occurring increases. However, advances in technology over the past 15 years have greatly reduced the likelihood of accidents caused by equipment malfunctions.

Studies done by Power Efficiency Corporation have shown the energy consumption of the escalator can increase by as much as 15 percent when a VVVF is installed, and the escalator is running constantly at full speed. Therefore, a VVVF may not be appropriate for all situations, such as in locations where the passenger flow is relatively constant.

Intermittent Drive with Regenerative Drive

Overview—Escalators equipped with intermittent drives can be used in conjunction with regenerative drives to produce significant energy savings. An intermittently run escalator stops or slows the escalator when passengers are not present and increases the speed of the unit to normal operating speeds when passengers approach the entrance. When paired with a regenerative drive, energy is recovered when the escalator is moving in a downward direction with passengers present.

Regenerative drives are one of the latest developments in escalator technology that focuses on recovering escalator energy and converting this energy to electricity. When passengers are being transported on a moving escalator, the drive motor acts like a generator (asynchronous motor) and energy is produced. In a traditional escalator, this energy is converted into heat using dynamic braking resistors. The regenerative drive controls the escalator load under all conditions and sheds excess energy by converting the energy into electricity and feeding it safely back into the supply network for use in building lighting or other applications. This technology can be used in conjunction with soft start-up or intermittent start–stop drives. A soft starter is a device that temporarily reduces the torque and current surge of the motor during startup. This reduces the mechanical and electrical stress on the motor, thus extending the lifespan of the system. The basic requirements of soft start-up and intermittent start–stop can be programmed into a regenerative drive.

When using a regenerative system, special care has to be taken to ensure that the regenerated power is of sufficient quality to be accepted into the grid and that the grid is fully protected from short circuits and disturbances.

Standard inverter drives have an input section, a power reservoir, and an output section. In general, they operate with energy freely flowing in both directions through the output (inverter) sections, but the input section is a diode bridge that only permits energy to flow in one direction. Regenerative drives maintain these three sections, allowing power to flow in both directions across the input, as well as the output, section. This is achieved by merging two inverters back to back. The additional input inverter allows power to flow from the power distribution system to the power reservoir when needed, and allows unimpeded reverse flow into the power distribution system when the reservoir is above normal operating levels.

When the escalator motor is under load, the input inverter circuitry is automatically operated to allow the power supply to pass through and maintain the power reservoir at the optimum

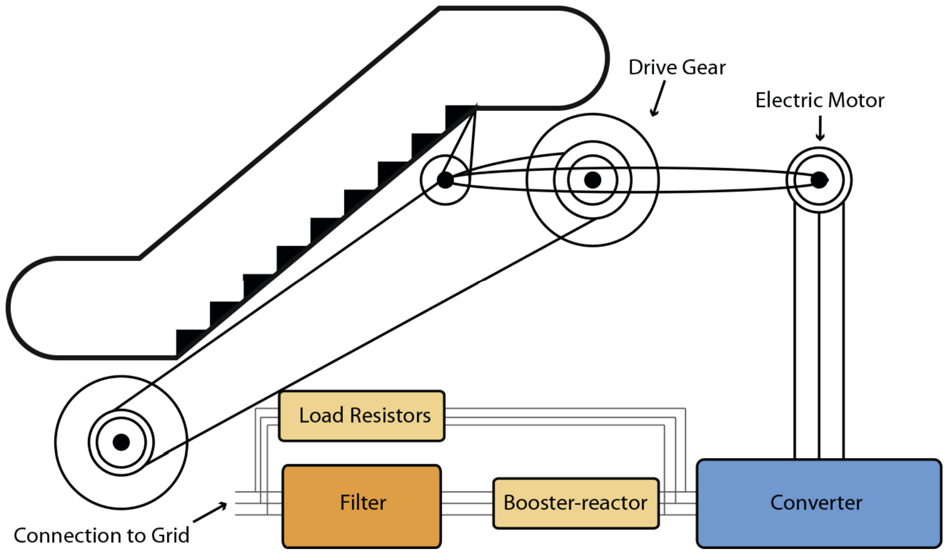


Figure 3-8. General configuration of a regenerative drive on an escalator.

condition. When the passenger load reaches enough mass to drive the escalator down without the assistance of the motor, the electric motor acts as a generator and energy is passed back through the output inverter section and feeds into the power reservoir. Under these conditions, the regenerative drive switches the excess power using the input inverter action to return the excess energy to the power distribution system. An important function of the input inverter is to synchronize the regenerated power with the phase rotation of the incoming power distribution system. See Figure 3-8 for a typical regenerative drive configuration on an escalator.

Benefits—According to one escalator manufacturer, an escalator equipped with a regenerative drive that captures energy generated by the escalator and delivers this energy back to the building for use by other systems can reduce energy consumption by up to 50 percent when compared to a traditional escalator.[20] Combining the intermittent drive with regenerative technologies results in greater savings than when using each technology alone. In addition, the regenerative drive produces clean, safe energy that has added environmental and carbon footprint benefits.

Limitations—The energy savings as a result of regenerative drive will not be achieved on a moving walkway. In addition, as stated earlier, the intermittent operation of an escalator has limited applicability. It is not suitable where escalators are in constant use as this leaves little to no opportunity for reasonable savings.

Also, the electrical distribution within the building may not always be able to accept the regenerated electrical energy. If there is no constant need for the regenerated energy, the payback of installing a regenerative drive may be excessive. In addition, braking resistors will still be required to dissipate the heat from the energy that cannot be repurposed.

Due to significant added installation cost, regenerative drives are not always cost effective, especially in areas with reduced traffic. Also, retrofitting an escalator to run intermittently or replacing it with a new intermittent-run escalator is expensive. As stated earlier, in some situations, there may not be enough space for the installation or architectural changes necessary to provide the needed space may be cost prohibitive.

[20] "Sustainable Products: Drive Systems," ThyssenKrupp Elevators, http://sustainability.thyssenkrupp-elevator.com/en/products/drive-systems/

Technologies Not Included in the Financial Tool

Although the following technologies are often recommended as energy saving options for escalators and moving walkways, the report authors chose to exclude these technologies from the financial tool for one of the following reasons:

- The technology may result in low energy savings and, consequently, long payback periods;
- It may no longer be available for installation; or
- Limited data may be available, that does not allow for analysis to determine the costs and benefits of the technology.

Technologies excluded from the financial tool and discussed in the following section include:

- Regenerative drives,
- Wye-delta configured motors,
- Direct drives, and
- Intermittent drives with motor efficiency controller and variable voltage–variable frequency drive.

Regenerative Drives

Overview—Regenerative drives, as previously discussed, recover escalator energy and convert the energy to electricity. When an escalator is loaded, the drive motor acts like a generator and energy is added back to the grid. In a traditional escalator, this energy is converted into heat using dynamic braking resistors. The regenerative drive converts the excess energy into electricity and feeds it safely back into the supply network for use in the facility.

Regenerative drives as a single technology are not included in the accompanying financial tool since energy data for validation of the savings was not available. However, regenerative drives are offered by many escalator manufacturers and are a recommended technology for consideration on down escalators and, in some cases, for up escalators, depending on the average loading for the escalator.

Benefits—As stated earlier, regenerative drives can reduce an escalator's energy consumption by up to 50 percent compared to a traditional escalator.[21] Regenerative drives also reduce the heat generation from an escalator, which in turn, means a reduction in the cooling requirements around the unit.

Limitations—Regenerative drives only result in energy savings on escalators and are not recommended for moving walkways. In addition, the electrical building electrical distribution may not always be able to accept the regenerated electrical energy.

Regenerative drives can be expensive to install, and therefore have very long payback periods in applications without a constant need for the regenerated energy. In addition, braking resistors will still be required to dissipate the heat from the energy that cannot be repurposed.

Wye-Delta Configured Motors

Overview—Wye-delta motors can operate in the star configuration when there is low escalator traffic. When the motor is switched to star operation, it is supplied with lower voltage, resulting in lower torque. When several passengers enter the escalator (usually 5 passengers) the motor is switched to delta operation, and the motor voltage is returned to normal.

[21] "Sustainable Products: Drive Systems," ThyssenKrupp Elevators, http://sustainability.thyssenkrupp-elevator.com/en/products/drive-systems/

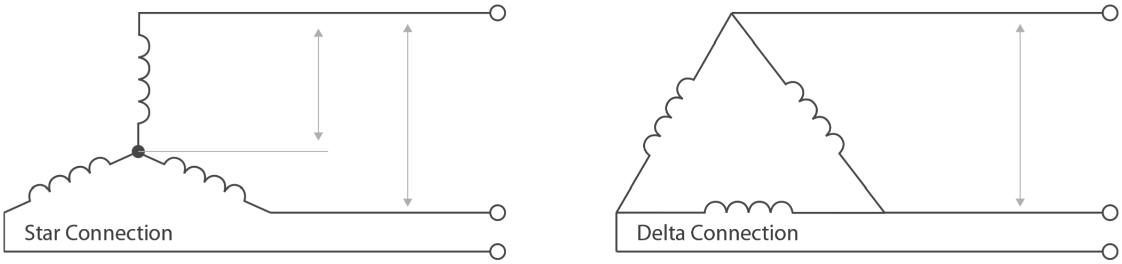


Figure 3-9. Wye (star) motor configuration versus delta motor configuration.

Three-phase motors have three windings. On some motors, all six ends are utilized (two ends per winding). On those motors, it is possible to connect the three windings such that they form a triangle shape (delta configuration), or a radial shape resembling the letter Y (wye or star configuration). One then connects the three power leads from the 3-phase source to three points in those configurations. See Figure 3-9.

Significant energy savings (up to 25 percent depending on passenger load) can be obtained in low passenger load situations when the motor is in the star configuration. A sensor will detect when a loading of approximately five or more people are present on the escalator. At this point, the unit switches to the delta contactor to allow for the added load. External electromagnetic contactors are used to change the motor windings between the two configurations.

When the windings of a three-phase motor are connected in star configuration, the voltage and current applied to each winding are reduced by approximately 57 percent ($1/\sqrt{3}$) of the voltage applied to the winding when it is connected in a delta. However, as a result, the total output torque when in a star configuration is only a third of the total torque it can produce when running in a delta.

Benefits—Installing a wye-delta configured motor can result in energy savings up to 25 percent depending on passenger load. The actual savings on a given escalator will depend on how often the unit is run in the star configuration.

Limitations—The wye-delta operation of an escalator has limited applicability. It is not suitable where escalators are constantly heavily loaded (5 or more passengers) as this leaves little to no opportunity for long enough intermittent periods to generate reasonable savings.

This technology was not included in the financial tool due to limited examples and available data for wye-delta motors being installed on escalators or moving walkways.

Direct Drives

Overview—A direct drive is a beltless and chainless drive connected directly to the main shaft of a motor. The direct drive takes the power coming from a motor without any reductions, such as a gearbox, thus maintaining motor efficiency. Being beltless and chainless eliminates the risk of slippage, belt or chain failure, and the need for oil. A direct drive consumes less electricity relative to other standard drives on the market.

A direct drive has increased efficiency because power is not wasted in friction from belts, chains, and gearboxes. Direct drives operate at reduced noise levels since there are fewer parts that are prone to vibration. Having fewer parts results in improved reliability, thus less potential for escalator downtime.

Benefits—The chainless drive eliminates the risk of chain failure and the need for oil. Fewer spare parts are needed due to the simple configuration and chainless design. Because the motor is directly coupled to the main shaft, efficiency increases and the power required to run the escalator is reduced.

Limitations—This technology was not included in the financial tool since it is no longer provided by escalator or moving walkway manufacturers. Retrofits may not be possible without significant space changes, thereby making this a cost-prohibitive technology.

Intermittent Drive with Motor Efficiency Controller and Variable Voltage—Variable Frequency Drive

Overview—An intermittently run escalator or moving walkway slows down or stops when passengers are not present and speeds up to normal operating speeds when a rider appears. By slowing down or stopping the electric motor driving the escalator, significant energy is saved. When paired with a MEC and VVVF, additional energy savings can be realized.

When connected to a down escalator, a MEC reduces voltage and current as each passenger boards. The motor will naturally draw less current but the MEC will reduce that current even more. This process continues until the motor current monitored by the MEC reaches a value just above zero. At this point, the MEC will transition to energy saving mode and turn on the silicon-controlled rectifiers (SCRs), allowing full voltage and current conduction back to the building's electrical distribution system. As the load increases, the motor starts running at the contact frequency. At this point, the motor actually stops using energy and starts producing energy, similar to a regenerative drive. The voltage and current have the same characteristics as the building distribution system, therefore no harmonic disturbance is created in the building distribution system.

The intermittent drive operating in the same load condition on a downward escalator will not reduce the current to the motor. The motor under the load on the escalator will naturally draw less current, although the motor voltage will stay the same. This will result in a higher energy usage compared to the MEC when the escalator is loaded. When the load reaches below zero current and the motor starts to produce energy, this power is sent back to the inverter. To control the rated speed of the down escalator, the inverter takes this excess power and diverts it to dynamic braking resistors. This excess power from the motor is turned into heat in these resistors and never goes back to the building distribution system. Therefore, this excess power is not available for use somewhere else in the building.

This technology will require motion sensors to detect an approaching passenger. Some escalator manufacturers use light barriers or contact mats to detect passengers. It is important that whatever the detection method used, it is reliable to ensure that the escalator will not change speed while there are passengers on the moving steps.

Benefits—The motor efficiency controller can save an average of 20 percent on escalators when the escalator is running at high speed. The intermittent drive saves additional energy depending upon the amount of time the escalator spends running in slow mode. When monitoring both an upward and a downward escalator, it is common to see the savings on the downward escalator to be higher than on the up escalator. This is due to the regenerative nature of the downward escalator.

Theoretically, if both are installed on an escalator, the MEC will prevent the energy consumption of an escalator or moving walkway from increasing when at full speed due to the installation of the VVVF. With both technologies installed on an escalator or moving walkway, the benefits from each technology will be distinctly apparent; however, the limitations for each technology will still apply.

Limitations—Of the manufacturers contacted for this project, none currently offer this grouping. In addition, limited examples of the technology configuration were available at the time of the study. Since limited data was available for this technology configuration, methodologies for calculating the potential savings could not be developed or validated, and the configuration could not be included in the accompanying financial tool.

Most of the limitations that apply to the intermittent drive, MEC, and VVVF still apply when the technologies are used together. The intermittent operation of an escalator is not suitable where escalators are in constant use as this leaves little to no opportunity for long enough intermittent periods to generate reasonable savings. Retrofitting an escalator to run intermittently or replacing it with a new intermittent-run escalator also can be expensive.

Summary of Technologies

Table 3-1 provides a summary of the technologies, including their benefits and limitations.

Table 3-1. Summary of technologies included in the financial tool.

Technologies	Overview	Benefits	Limitations
LED Lighting	An LED, or light-emitting diode, is a semiconductor light source that consumes significantly less energy than typically used light sources such as incandescent lights.	LED lighting can reduce lighting consumption by up to 38 percent and last much longer than other types of lighting.	LED lighting may appear slightly dimmer compared to T8 and T12 lighting.
Capacitors	A capacitor is a passive two-terminal electrical component used to store energy and improve the power factor of an electrical line.	Capacitors help avoid losses due to low power factor and penalty fees charged by utilities due to poor power factor.	If the power factor on an escalator/moving walkway unit is fair to start with, the payback period for capacitors can be high. Capacitors also should not be installed on distribution systems with high harmonics since harmonics can cause capacitors to fail.
High-Efficiency Motors	High-efficiency motors are motors with 1 percent to 10 percent higher efficiency than standard motors because of less internal loss in the motor due to power losses and magnetic core losses. Fully loaded efficiency of a typical high-efficiency motor is 90.2 percent.	Significant energy savings can be achieved and the useful life of the motor can be lengthened.	High-efficiency motors are not compatible with all applications. Modifications may need to be made to the drive system or motor controls if a high-efficiency motor is installed. In addition, high-efficiency motors often cost 15 to 25 percent more than standard motors.
Motor Efficiency Controllers (MECs)	A motor efficiency controller (MEC), also known as a sinusoidal drive, is a solid-state controller that dynamically optimizes the efficiency of a 3-phase alternating current (AC) induction motor.	A savings of 10 to 25 percent can be achieved depending on the load factor and escalator direction. MECs also reduce the operating temperature of the motor, thereby reducing maintenance costs and prolonging its useful life.	Little savings are seen on systems that are over 75 percent loaded.
Intermittent Drives	Intermittent drives reduce the speed of an escalator when no passengers are present. A sensor is placed at the entrance and the exit of a moving walkway or escalator. When the sensor detects that no passengers are present, the motor controller reduces the speed of an escalator or moving walkway to a minimally accepted speed.	Intermittent drives can result in significant savings. Since intermittent drives reduce the speed of an escalator/moving walkway when passengers are not present, they also increase the useful life of the motor and reduce maintenance costs.	Little savings can be achieved on escalators/moving walkways on which passengers are always present. Installing an intermittent drive can be costly and may require modifications to the surrounding area to allow enough space for the sensors. In addition, not all states have adopted the ASME 17.1 2010 code that allows escalator/moving walkway speeds to be variable.
Intermittent Drives (Start–Stop) with MECs	Intermittent drives can be paired with a MEC. If paired together, to maximize savings potential, it is recommended that the escalator be brought to a complete stop when no passengers are present.	When paired together, the savings achieved for an escalator/moving walkway is higher than when only one technology is installed.	The limitations that apply to the intermittent drive and MEC still apply when the technologies are paired together.

(continued on next page)

Table 3-1. (Continued).

Technologies	Overview	Benefits	Limitations
Intermittent Drives with Variable Voltage–Variable Frequency Drives (VVVF)	A VVVF is a motor controller that regulates the voltage and frequency delivered to a motor depending on the loading. When paired with a sensor, the VVVF can act as an intermittent drive. When passengers are not detected by the sensor, the escalator/moving walkway can either be slowed to a minimum allowable speed or brought to a complete stop when no passengers are present.	If an escalator is frequently found running when passengers are not present, significant savings can be achieved with a VVVF, and the useful life of the motor can be lengthened.	The limitations that apply to the intermittent drive still apply when the technology is paired with a VVVF. Due to the installation of the VVVF, the energy consumption of the escalator/moving walkway may be increased when the unit is fully loaded.
Intermittent Drives (Start–Stop) with Regenerative Drives	Intermittent drives can be paired with a regenerative drive. When paired with a regenerative drive, the motor acts like a generator (asynchronous motor) and energy is produced when the escalator is moving downward and, in some cases, in the up direction.	This technology pairing not only reduces the energy consumption of the unit, but can supply energy to the electrical grid.	The installation cost for this pairing is the highest of all the technology pairings discussed in this report. The limitations that apply to the intermittent drive still apply when the technology is paired with a regenerative drive. In addition, the electrical supply grid may not always be able to accept the escalator-regenerated electrical energy.

Technologies vs. Potential Savings

Potential savings of various technologies are provided in Table 3-2.

Table 3-2. Potential energy savings.

Technology(ies)	Average Potential Savings
LED Lighting	30 to 40 percent*
Capacitors	0.5 to 2 percent
High-Efficiency Motors	2 to 18 percent**
Motor Efficiency Controllers (MEC)	10 to 25 percent
Intermittent Drives	15 to 25 percent
Intermittent Drives (Start–Stop) with MECs	30 to 35 percent
Intermittent Drives (Slow down) with Variable Voltage–Variable Frequency Drives (VVVF)	-15 to 57 percent
Intermittent Drives (Start–Stop) with Regenerative Drives	30 to 50 percent (excludes moving walkways)

* On lighting energy consumption only.
** Depends on loading and motor horsepower.

CHAPTER 4

How to Select and Implement Energy Saving Technologies

Selecting and verifying energy savings technologies can be difficult due to the variability in escalator and moving walkway usage and passenger flow. Several key metrics should be collected and measured prior to the installation of any energy saving technologies in order to identify, review, and select the most sensible and location-specific energy efficient technologies.

Key parameters that should be evaluated prior to selecting energy saving technologies include the following:

- Escalator/moving walkway passenger traffic/flow;
- Energy saving technologies currently installed;
- Age and operation of escalators/moving walkways;
- Clearances/space available to install new technologies;
- Safety considerations (ASME 17.1); and
- Length, width, height of escalator/walkway.

Gathering the necessary data takes time. It is very important that the escalator/moving walkway passenger flow be as complete and accurate as possible. Depending on airport size, this could take several weeks.

Once an airport manager has gathered all of the data available, he or she can determine which energy saving technologies may have the potential for effective installation and use in the airport based on the technology information contained in this report. The financial tool can then be used to analyze each of these potential technologies to determine the following:

- Total energy savings of selected technologies,
- Financial payback period,
- Return on investment (ROI), and
- Net present value (NPV).

The airport manager can take the output of the financial tool and use it to justify the project to the decision-making body.

Overview of Process

The following section discusses the steps for selecting and implementing an energy saving project. Although this section was written for escalator and moving walkway projects, the steps described also can be applied to other energy saving projects within the airport.

Step 1: Define Project Scope and Develop Objectives

The first step of the process is to develop a scope for the project and define the objectives. This can be done by first answering a set of questions about the project. Sample questions that should be answered when developing the project scope include the following:

- What are the criteria for selecting which escalators and moving walkways will be updated (e.g., age, location, etc.)?
- How many escalators/moving walkways will be updated?
- What are the criteria for selecting which technologies to install (e.g., payback, initial cost, annual cost savings, etc.)?
- What code or safety limitations are present that may exclude certain technologies? For example, if the state has not adopted the ASME 17.1 2010 and a variance cannot be obtained, intermittent drives will not be a viable option.

During Step 1, also develop objectives or goals for the project. Examples of project goals are as follows:

- Reduce annual escalator energy consumption by 10 percent.
- Eliminate utility fees for poor power factors on escalators/moving walkways.

Step 2: Collect Data

Collect the data recommended in the previous step for each escalator/walkway being considered for the project. A printable data collection form is provided in Appendix A.

It is important that the data samples include a representation of all passenger traffic flow patterns. The financial tool collects the passenger flow for given time periods inclusive of the entire time the escalator is in use. The passenger flow not only has a significant impact on the system's energy use in current conditions, but also has a significant impact on the potential savings associated with each of the energy saving technologies considered.

If there are plans to evaluate a return on investment (ROI) that includes the cost of the overall project, then a request for estimates from the manufacturer is warranted. Technologies can be evaluated with the financial tool without manufacturing costs but will only focus on energy saved.

Step 3: Evaluate Options for Savings and Select an Approach

Use the financial tool to evaluate the various technologies or combinations of technologies being considered for the project. A detailed description on how to use the financial tool is included in Chapter 5. The financial tool calculates the following metrics:

- Current energy consumption and cost per year,
- Potential energy consumption and cost per year with the implementation of a user-selected energy saving technology,
- Potential annual energy and cost savings,
- Payback period,
- Return on investment (ROI), and
- Cost savings over the life of the escalator.

The financial tool and this report do not provide cost estimates for the installation of a given technology. Several variables impact the cost of installation. Therefore, cost estimates are not provided in the financial tool. The location of the escalator, manufacturer, and difficulty of installation are just a few variables that impact total installation cost.

In addition to the metrics calculated by the financial tool, relevant regulations and safety impacts should be considered. For example, the following decision factors should be considered:

- Impact on passenger safety,
- Compliance with state regulations, and
- Impact on insurance costs.

Step 4: Receive Approval from Management

After the project scope, potential savings, impact on safety, code compliance, and other important decision-making factors are determined, the next step is to receive approval from management. Individuals and groups that may have a stake in whether the project will be implemented include the following:

- Lead engineer,
- Chief executive officer (CEO),
- Chief operating officer (COO),
- Legal department, and
- Finance department.

The Output Sheet of the financial tool accompanying this report is formatted to be printed and presented to management. However, it should be noted that the energy savings, cost savings, payback, and other financial metrics shown in the tool are estimates. In addition to the information presented in the financial tool, code and safety considerations also should be presented to management.

Step 5: Implement Approach

After a technology is selected and approval is received from management, the next steps are to receive quotes from manufacturers and to implement an approach. Table 3-2 lists the major manufacturers that participated in this project and the technologies each supplies.

Manufacturers may use different product names to refer to the same technology. For example, the motor efficiency controller is often referred to as the Soft Start, Sinusoidal Drive, E-Save, or by another name unique to the manufacturer.

Step 6: Evaluate Performance

If metering equipment is available, a recommended but optional step is to measure and verify the energy savings as a result of the upgrade. This step requires that baseline energy readings be taken prior to the installation. It is recommended that the baseline measurements and post-upgrade measurements be taken for 24 hours per day over a 7-day period to ensure all passenger flow scenarios are covered. Measurements taken before and after the upgrade should be taken with the same equipment to ensure consistency. Equipment that may be required to verify the savings include the following:

- Three-phase electrical energy meter with data logging,
- Watt meter with data logging, and
- Multimeter with data logging.

Monitoring performance not only allows verification that the system is performing as expected, but also helps to identify potential issues with the installation. If the proper metering equipment is available, measurements should be taken regularly throughout the year to verify that the equipment continues to perform as expected. If the energy use of the unit changes significantly, this would be an indicator that the configuration or settings on a component of the system may have changed over time and need to be reset.

Evaluating performance also can benefit the management approval process for future projects. The ability to refer to a previously validated, successful project will reinforce confidence in future projects.

CHAPTER 5

How to Use the Financial Tool

Overview

The goal of the financial tool is to provide a quantitative assessment of proposed energy saving projects for a single escalator or moving walkway, or a group of escalators or moving walkways. The financial tool analyzes various technologies to calculate key metrics, including the following:

- Potential annual energy savings for selected technology(ies), relative to baseline values;
- Potential annual cost savings for selected technology(ies), relative to baseline values;
- Financial payback period;
- Return on investment (ROI); and
- Potential cost savings over the life of the system, relative to baseline values.

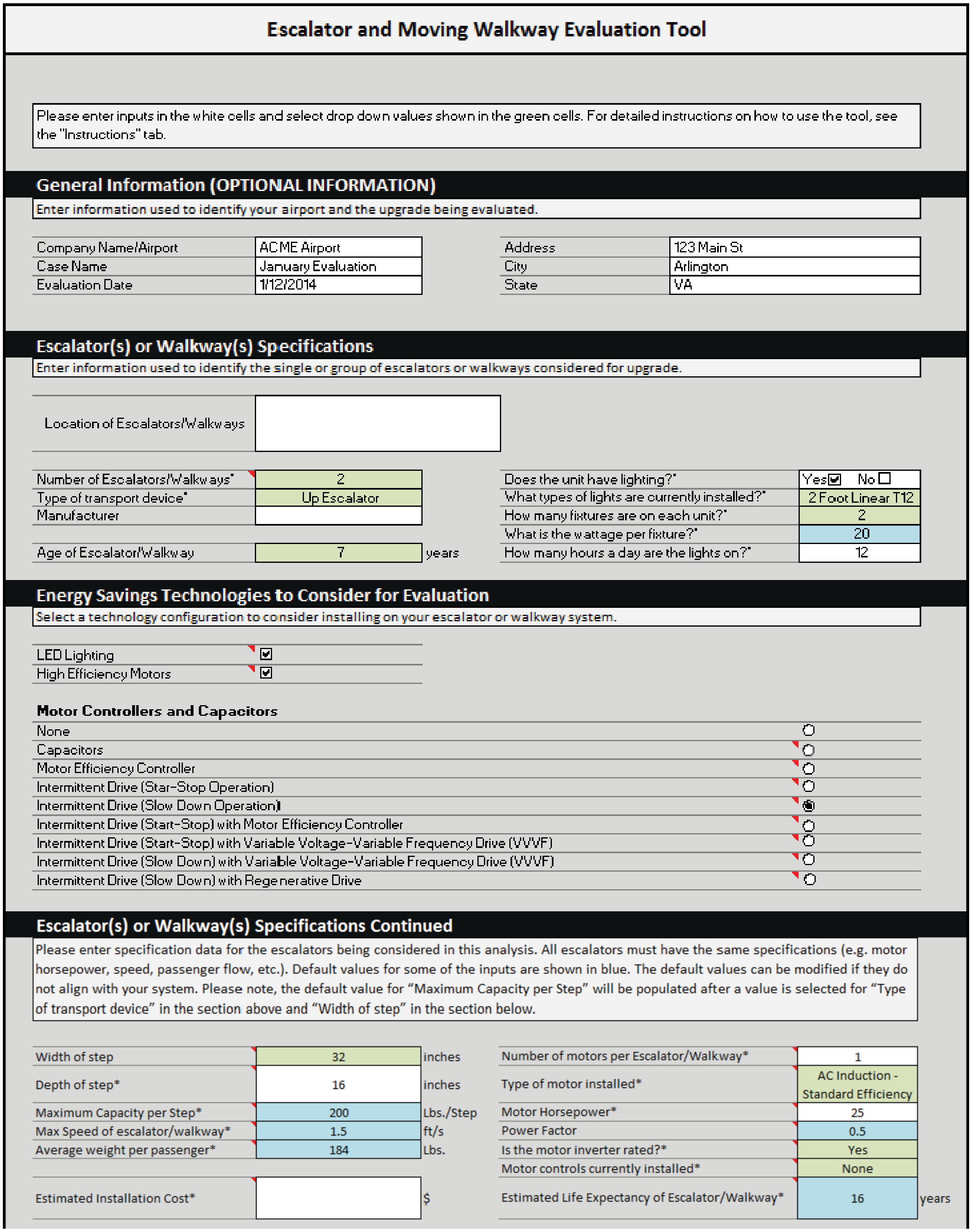
How to Calculate Outputs

The following section discusses the steps required to run the financial tool.

Step 1: Enter Escalator/Walkway Information for the Current System

To generate cost and financial metrics for an evaluation case, it is first necessary to enter information for the current escalator/moving walkway configuration, as shown in Figure 5-1. This information is entered in the Inputs Tab of the workbook. Although all of the information contained in the Inputs Tab is helpful for tracking an evaluation case, not all information is necessary in order to generate outputs. The information required to produce outputs is as follows:

- Number of escalators/moving walkways,
- Type of transport device,
- Width of step,
- Depth of step,
- Maximum capacity,
- Speed of escalator/moving walkway,
- Average weight per passenger,
- Estimated installation cost,
- Number of motors per escalator/moving walkway,
- Type of motor installed,
- Motor horsepower,
- Full load efficiency,
- Power factor,
- Whether the motor is inverter rated,
- Motor controls currently installed,



Escalator and Moving Walkway Evaluation Tool

Please enter inputs in the white cells and select drop down values shown in the green cells. For detailed instructions on how to use the tool, see the "Instructions" tab.

General Information (OPTIONAL INFORMATION)

Enter information used to identify your airport and the upgrade being evaluated.

Company Name/Airport	ACME Airport	Address	123 Main St
Case Name	January Evaluation	City	Arlington
Evaluation Date	1/12/2014	State	VA

Escalator(s) or Walkway(s) Specifications

Enter information used to identify the single or group of escalators or walkways considered for upgrade.

Location of Escalators/Walkways				
Number of Escalators/Walkways*	2		Does the unit have lighting?*	Yes ☑ No ☐
Type of transport device*	Up Escalator		What types of lights are currently installed?*	2 Foot Linear T12
Manufacturer			How many fixtures are on each unit?*	2
			What is the wattage per fixture?*	20
Age of Escalator/Walkway	7	years	How many hours a day are the lights on?*	12

Energy Savings Technologies to Consider for Evaluation

Select a technology configuration to consider installing on your escalator or walkway system.

LED Lighting	☑
High Efficiency Motors	☑

Motor Controllers and Capacitors

None	○
Capacitors	○
Motor Efficiency Controller	○
Intermittent Drive (Star-Stop Operation)	○
Intermittent Drive (Slow Down Operation)	◉
Intermittent Drive (Start-Stop) with Motor Efficiency Controller	○
Intermittent Drive (Start-Stop) with Variable Voltage-Variable Frequency Drive (VVVF)	○
Intermittent Drive (Slow Down) with Variable Voltage-Variable Frequency Drive (VVVF)	○
Intermittent Drive (Slow Down) with Regenerative Drive	○

Escalator(s) or Walkway(s) Specifications Continued

Please enter specification data for the escalators being considered in this analysis. All escalators must have the same specifications (e.g. motor horsepower, speed, passenger flow, etc.). Default values for some of the inputs are shown in blue. The default values can be modified if they do not align with your system. Please note, the default value for "Maximum Capacity per Step" will be populated after a value is selected for "Type of transport device" in the section above and "Width of step" in the section below.

Width of step	32	inches	Number of motors per Escalator/Walkway*	1	
Depth of step*	16	inches	Type of motor installed*	AC Induction - Standard Efficiency	
Maximum Capacity per Step*	200	Lbs./Step	Motor Horsepower*	25	
Max Speed of escalator/walkway*	1.5	ft/s	Power Factor	0.5	
Average weight per passenger*	184	Lbs.	Is the motor inverter rated?*	Yes	
			Motor controls currently installed*	None	
Estimated Installation Cost*		$	Estimated Life Expectancy of Escalator/Walkway*	16	years

Figure 5-1. Tool input screen.

- Estimated life expectancy of escalator/moving walkway,
- Number of passengers,
- Start time,
- End time,
- Unit electricity cost, and
- Percentage of time not in use.

Step 2: Select a Technology Configuration for Evaluation

To evaluate a technology configuration, users must select the technology(ies) to be evaluated in the Inputs Tab section named "Energy Savings Technologies to Consider for Evaluation."

Note that only one technology configuration (i.e., a single technology or a combination of technologies) may be selected with the exception of LED lighting and high-efficiency motors, which may be combined with one other technology configuration. Also, if a motor is not indicated as being inverter rated in the "Escalator(s) or Walkway(s) Specifications Continued" section of the Inputs Tab, then only LED lighting, capacitors, or high-efficiency motors can be evaluated.

Step 3: Enter Average Passenger Flow Data

The Average Passenger Flow Table contained in "Escalator(s) or Walkway(s) Specifications Continued" allows for the tracking of usage information, such as passenger flow and usage percentage, as well as unit electricity cost information for a given time period. To accurately evaluate an escalator/moving walkway configuration, the Average Passenger Flow Table should contain information for an entire day of operation.

The Average Passenger Flow Table, pictured in Figure 5-2, has the capacity to track information for up to 24 discrete time periods. If needed, another row can be added to

Average Passenger Flow

In the section below, fill out the average number of passengers over the selected time span along with the corresponding unit electricity cost and the percent of time the escalator/moving walkway is not in use. An average rate including all extra charges (generation, distribution, transmission, demand, power factor etc.) should be entered for the unit electricity cost. Please note, cost savings calculated by the tool do not consider reductions in demand charges for rescheduling loads.

In order to accurately evaluate an escalator/moving walkway configuration, the Average Passenger Flow Table should contain information inclusive of an entire day of operation. For additional information regarding the data required for each column, hover over the column name to see the tool tip.

The Average Passenger Flow table has the capacity to track information for up to 24 discrete time periods. If it is necessary to add another row to the table, click the button "Add More Rows," located underneath the Average Passenger Flow table.

Number of passengers*	Start Time*	End Time*	Unit Electricity Cost ($/kwh)*	Percent of Time not in Use*
200	5:00 AM	8:00 AM	0.1	30%
120	8:00 AM	9:00 AM	0.08	10%
300	9:00 AM	12:00 PM	0.15	10%
400	12:00 PM	5:00 PM	0.2	10%
600	5:00 PM	11:00 PM	0.2	20%

Add More Rows | Calculate Savings | Reset

Figure 5-2. Average Passenger Flow Table.

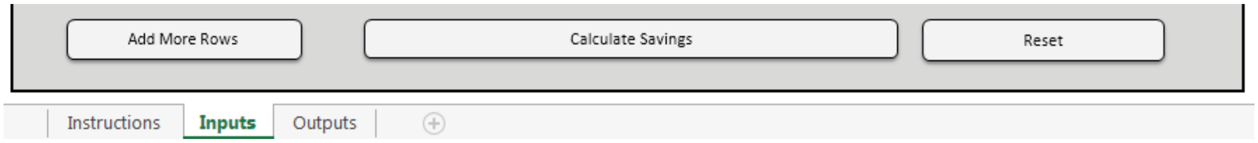


Figure 5-3. Calculate Savings Button.

the table by clicking the Add More Rows Button located beneath the Average Passenger Flow Table.

Step 4: Calculate Outputs

After entering the required inputs as identified in the previous section, click the Calculate Savings Button located in the Inputs Tab as shown in Figure 5-3. This will generate the following outputs shown in Figures 5-4 and 5-5:

- Current and Potential Energy Consumption: Contains information regarding current and potential escalator/moving walkway energy consumption.
- Cost and Other Financial Considerations: Contains information regarding current and potential annual escalator/moving walkway energy cost, along with financial metrics to support project evaluation. Note that if no installation cost value is entered in the Inputs Tab, or if the installation cost is $0, then financial metrics will not be calculated.
- Technology Limitations: Displays information regarding limitations for technologies selected to be evaluated. This information can be hidden by clicking the Hide Assumptions & Limitations Button located in the Outputs Tab.

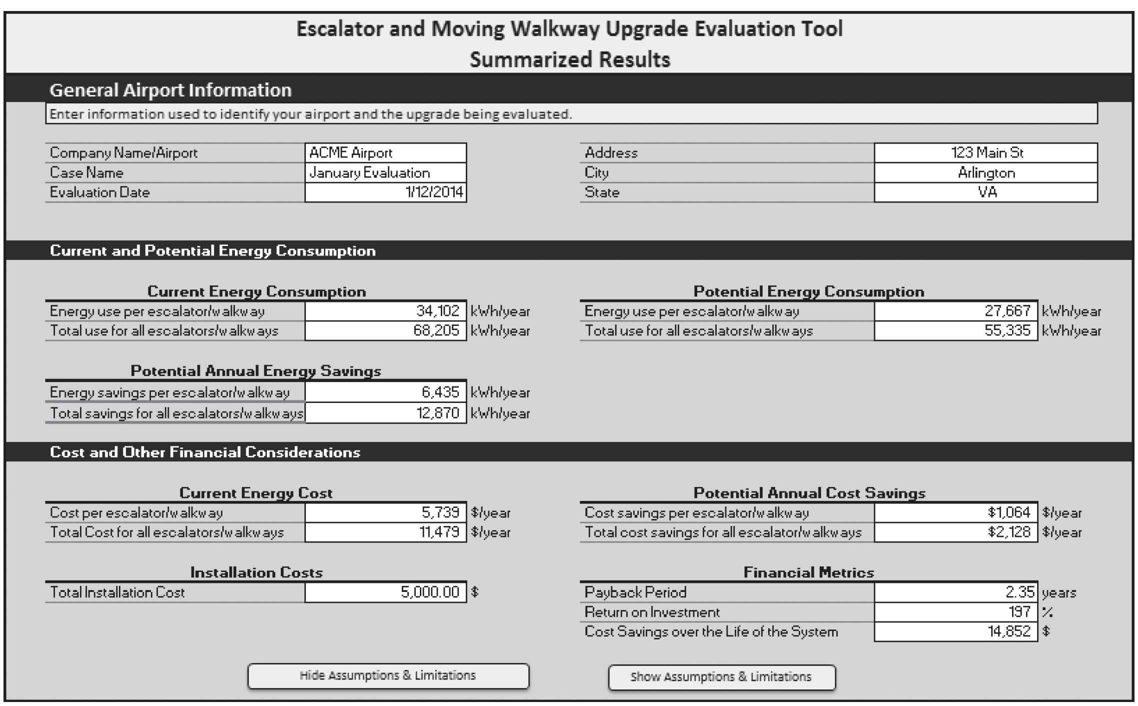


Figure 5-4. Summarized outputs.

Technology	Limitations
LED Lighting	LED or Light Emitting Diode lighting is a semiconductor light source which can be used above the skirt panel throughout the length of the step band, under the handrail, and below the step at the top and bottom landings on an escalator or moving walkway. LED lighting can also be used for indicator signs at the entrance to the escalator and/or moving walkway. Studies have shown that LED lighting can reduce the lighting energy consumption by up to 38%. LED lights also require less maintenance since they have a longer lifetime.
High Efficiency Motors	As the name implies, high efficiency motors have higher efficiencies than standard motors and result in reduced energy consumption due to the increased efficiency. The most common AC motor seen in escalators are the induction asynchronous squirrel-cage motors, composed of an external stator core and rotating rotor. The standard fully-loaded efficiency of induction motors is around 84%, whereas the typical efficiency of a NEMA premium efficiency motor is 90.2%. By replacing the motor in an escalator, savings are not only achieved due to the higher efficiency, but often times the motor selected for an escalator or moving walkway system is oversized. Significant savings can be achieved by selecting an accurately sized motor. High efficiency motors may not be compatible for all escalator and moving walkway systems. Modifications may need to be made to the drive system or motor controls if a premium efficiency motor is installed. An escalator or moving walkway manufacturer should be consulted prior to replacing the motor. In addition, premium-efficiency motors often cost 15-25% more than standard motors depending on the size.
Intermittent Drive (Slow Down Operation)	Intermittent drives reduce the speed of an escalator when no passengers are present. A sensor is placed at the entrance and exit of a moving walkway and/or escalator. When the sensor detects that no passengers are present, the motor controller reduces the speed of the escalator or moving walkway to a minimally accepted speed (10 ft. per second). When the sensor detects passengers approaching the escalator, the motor controller than increases the speed to the full speed. In practice, intermittent drives typically result in the highest savings, especially when the intermittent drive is programmed to bring the escalator to a complete stop. If an escalator or walkway is located in a position in which passengers are always present, minimal savings will be achieved since the escalator or moving walkway will continue to run at all times. The most recent American Society of Mechanical Engineers (ASME) code A17.1: Safety Code for Elevators and Escalators allows the speed of the escalator or moving walkway to change after start-up. The minimum speed allowed is 10 feet per minute; however, variations have been made to allow the escalator to come to a complete stop. The code has not yet been adopted in all states. If the code has not been adopted in the state in which the installation is being considered, a variance may be applied for to allow the escalator speed to change despite the code not being adopted yet.

Figure 5-5. Detailed outputs.

After clicking the Calculate Savings Button, an error message may appear. If an error message is encountered, the tool will not calculate output values. To calculate output values, the error must be corrected. Potential error messages and corresponding troubleshooting responses are shown in Table 5-1.

Step 5: Reset the Financial Tool

To reset the financial tool and begin a new evaluation case, click the Reset Button located beneath the Average Passenger Flow Table in the Inputs Tab. This will clear all information entered for an evaluation case, with the exception of the default values shown in Table 5-2.

Table 5-1. Financial tool error messages.

Error Message	Error Fix
Please enter a value for Installation Cost.	Enter a numerical value for estimated installation cost in the section for Escalator(s) or Walkway(s) Specifications Continued in the Inputs Tab.
If a motor is not inverter rated, then only LED lighting, capacitors, or high-efficiency motors can be evaluated.	If the answer to the question "Is the motor inverter rated?" in the section on Escalator(s) or Walkway(s) Specifications Continued of the Inputs Tab is "No," then ensure that only LED lighting, capacitors, or high-efficiency motors are selected to be evaluated.

Table 5-2. Financial tool default values.

Field	Value
What is the wattage per fixture?	Calculated value, dependent on the type of lights currently installed
Maximum capacity per step	Calculated value, dependent on whether a moving walkway is being evaluated, and the value for width of step
Maximum speed of escalator/moving walkway	1.5 feet/second
Average weight per passenger	184 lbs
Estimated life expectancy of escalator/moving walkway	16 years
Power factor	0.5

CHAPTER 6

Best Practices

Low to no-cost measures can be taken to reduce the energy consumption of an escalator or moving walkway. Proper maintenance of an escalator and moving walkway not only helps to prevent accidents and prolong the useful life of the unit, but also can help reduce energy use.

Although not part of the original research effort, the team identified several maintenance best practices that, if implemented, are likely to improve moving walkway and escalator performance as described in this chapter.

Sources for the best practices discussed in Chapter 6 include the following:

- Building Owners and Managers Association of British Columbia, *Best Practices for All Elevators and Escalators in British Columbia;*
- Government of Western Australia Department of Commerce, *Safety Standards for Escalators and Moving Walkways;*
- Transportation Research Board, *Transit Cooperative Research Program (TCRP) Synthesis 100: Elevator and Escalator Maintenance and Safety Practices;* and
- University of Michigan Elevator Shop.

Best Practice 1: Minimize Operating Hours

If the ASME 17.1 2010 Code has not been adopted in an airport's state and the airport cannot receive a variance to install an intermittent drive or does not have the initial capital to afford the installation, they can still benefit from turning the escalator off when passengers are not present.

If not run 24 hours a day, escalators and moving walkways are often started early in the morning before many passengers are present and continue to run after the crowds have left. In addition, many terminals often have multiple escalators or moving walkways moving in the same direction. This is often to prevent crowding at the escalator entry or exit during peak times. During times when few passengers are present, escalators should be turned off to avoid excess energy consumption.

Best Practice 2: Lubricate Components to Reduce Friction Losses

One of the most significant losses in escalators and moving walkways is friction loss. Friction losses can be minimized through the use of proper lubrication. The following components should be lubricated on a regular basis:

- Brakes;
- Step connections;

- Rolls, roller tracks, chains, and gears;
- Handrails;
- Drive machine motor and reduction gear; and
- Connection between the motor and main drive shaft.

In addition to ensuring that the components of the escalator and moving walkway are properly lubricated, the components should be inspected regularly to ensure proper alignment. If the guide rails or shoes become misaligned, friction losses will increase.

Best Practice 3: Install Energy Meters

Energy meters not only help to develop a baseline energy use for an escalator/moving walkway and determine potential energy savings, but also can help notify maintenance staff when a part is not performing correctly. Escalators and moving walkways often have sensors and communications systems that notify the airport staff when an escalator has stopped or is malfunctioning. Many of these systems can be programmed to monitor energy consumption. Many escalator monitoring systems also can be programmed to send notifications to a computer or cell phone when an escalator is down, and can measure and record the energy consumption of an escalator/moving walkway. By using monitoring devices, airport maintenance staff can detect when the energy use of a unit increases drastically. Unusual energy spikes are a good indicator that an escalator or moving walkway component (e.g., motor controller or motor) may be malfunctioning.

Additionally, many of the modern controllers discussed in this report have built-in energy monitoring capabilities. When combined with information regarding traffic patterns, load, and idle times, energy data captured by monitors and controllers can help the airport identify methods for improving a unit's energy performance.

Best Practice 4: Clean Escalator Components Regularly

Annual cleaning of the escalator components can help improve the energy performance of an escalator or moving walkway. Annual cleaning helps to reduce friction losses and aids airport staff in identifying failing components. The following components should be cleaned regularly:

- Steps/pallets and treadways;
- Drip pans;
- Rolls, roller tracks, and chains;
- Handrails;
- Skirts/comb plates;
- Drive machine motor and reduction gear; and
- Brake on drive machine.

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Acronyms

The following acronyms are defined in this document.

Term	Definition
AC	Alternating Current
ANSI	American National Standards Institute
ASD	Adjustable-Speed Drive
ASME	American Society of Mechanical Engineers
CEO	Chief Executive Officer
CO_2	Carbon Dioxide
COO	Chief Operating Officer
DC	Direct Current
EERE	Energy Efficiency and Renewable Energy
GSA	General Services Administration
kVA	Kilovolt-Ampere
kWh	Kilowatt-Hour
LED	Light Emitting Diode
MEC	Motor Efficiency Controller
NASA	National Aeronautics and Space Administration
NPV	Net Present Value
PF	Power Factor
PWM	Pulse Width Modulation
ROI	Return on Investment
SCR	Silicon-Controlled Rectifiers
SI	International System
VFD	Variable Frequency Drive
VV	Variable Voltage
VVD	Variable Voltage Drive
VVVF	Variable Voltage–Variable Frequency

Glossary

The following terms are used in this document.

Term	Definition
ASME 17.1	American Society of Mechanical Engineers (ASME) Safety Code for Elevators and Escalators
Capacitor	A passive electric component used to store energy electrostatically; used to increase power factor by counteracting inductive loading from electric motors to make load appear mostly resistive
Direct Drive	A chainless drive connected directly to the shaft of a motor without use of a gearbox, chain, or belts; has increased efficiency because power is not wasted in friction
Escalator	A load carrying unit designed to transport a wide variety of people, along with their luggage, at airports; escalators are driven by an electric motor and a drive system, which moves steps or belts with coordinated handrails at synchronized speeds
Fluorescent Lighting	All fluorescent lamps and certain other types of light bulbs contain mercury, and fluorescent lamps are the most common type of indoor light source for commercial and public buildings (Department of Ecology, State of Washington)
High-Efficiency Motor	A motor with 1–10 percent higher efficiency than standard motors due to less internal loss in the motor due to power losses and magnetic core losses; contains more copper and iron, which lowers losses but increases cost
Intermittent Drive	Motor controllers that slow down an escalator to either a complete stop or a lower speed when passengers are not present
LED Lighting	A semiconductor diode that emits lights when a voltage is applied to it and that is used especially in electronic devices (*Merriam-Webster Dictionary*)
Moving Walkway	A load carrying unit designed to transport a wide variety of people, along with their luggage, at airports; moving walkways are driven by an electric motor and a drive system, that moves steps or belts with coordinated handrails at synchronized speeds

Permanent Magnet Synchronous Motor (PMSM) A cross between an alternating current (AC) induction motor and a brushless direct current (DC) motor; the primary difference between a PMSM and an induction motor is that the rotor magnetic field is produced by the permanent magnets

Regenerative Drive A motor drive that captures energy on down escalators and converts this energy to electricity; when passengers are being transported on a down escalator, the drive motor acts like a generator (similar to an asynchronous motor) and energy is produced; the regenerative drive controls the escalator load under all conditions and sheds excess energy by converting the energy into electricity and injecting it safely back into the supply network for use in building lighting or other applications

Return on Investment (ROI) Profit from an activity for a period compared with the amount invested in it

Simple Payback The amount of time it will take to recover the initial investment, dividing initial design, purchase, and installation cost by the annual cost savings; does not factor in the time value of money

Variable Voltage–Variable Frequency Drive (VVVF) A motor controller that controls the voltage and frequency delivered to a motor, directly affecting the energy consumption of the motor

APPENDIX A

Data Collection Form

General Airport Information

Airport Name ____
Evaluation Date ____
Address ____
City ____
State ____

Escalator/Moving Walkway Specifications

Location of Escalator/Moving Walkway ____
Number of Escalators/Moving Walkways ____
Manufacturer ____

Does the unit have lighting? Yes ☐ No ☐
How many fixtures are on each unit? ____ Fixtures/unit
What is the wattage per fixture? ____ Watts/fixture
How many hours per day are the lights on? ____ Hours/day

What types of lighting are currently installed?
- 2 Foot Linear T8 ☐
- 2 Foot Linear T12 ☐
- 2 Foot Linear LED ☐
- 4 Foot Linear T8 ☐
- 4 Foot Linear T12 ☐
- 4 Foot Linear LED ☐
- Incandescent ☐
- Other:

Type of Transport Device
- Up Escalator ☐
- Down Escalator ☐
- Moving Walkway ☐

Operation Hours per Day ____ hours
Age of Escalator/Walkway ____ years

Number of Motors ____
Motor Horsepower ____ hp
Full Load Efficiency ____ %
Power Factor ____
Is the motor inverter rated? Yes ☐ No ☐

Step Width ____ feet
Step Depth ____ feet
Maximum Capacity ____ lbs
Escalator/Walkway Speed ____ feet/sec
Estimated Life Expectancy of Escalator/Walkway ____ years

Type of Motor
- AC Induction – Standard Efficiency Motor ☐
- AC Induction – Premium Efficiency Motor ☐
- Other:

Motor Controller Currently Installed
- Motor Efficiency Controller (MEC)/Sinusoidal Drive ☐
- Intermittent Drive (Start–Stop Operation) ☐
- Intermittent Drive (Slow down Operation) ☐
- None ☐

Passenger Flow

Average Passenger Weight ____ lbs./Passenger

Number of Passengers	Start Time	End Time	Unit Cost ($/kWh)	Percent of Time not in Use

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation