The following appendices are supplemental to *ACRP Research Report 252: Airport Baggage Handling System Decision-Making Based on Total Cost of Ownership* (ACRP Project 03-53, "Airport Baggage Handling System Decision-Making Based on Total Cost of Ownership"). The full report can be found by searching on the report title on the National Academies Press website (nap.nationalacademies.org).

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Appendix A Interview Findings: Detailed Components of TCO

A total of 31 interviews were conducted with airports, airlines, OEMs, Operations & Maintenance (O&M) providers, baggage handling subject matter experts (SMEs), General Contractors (GCs), and consultants. The purpose of these interviews was to provide a broad range of experience with projects currently considering deployment of a new system, implementing new systems, recently deployed systems, and operating older systems. These interviews focused on lessons learned from previous projects, features, and customizable options available to airports, and insight into next-generation technologies, in which the OEMs are investing research and development funding.

Some common themes arose during Total Cost of Ownership (TCO) study interviews. Below are the most common topics discussed with interviewees.

A.1 Top BHS Characteristics

One of the main topics discussed in the interviews was concerning the most critical attributes of a Baggage Handling System (BHS). Responses varied, but most interviewees agreed that the primary focus points are reliability, redundancy, expansion opportunity, optimum functionality, minimizing operational support personnel, and efficient maintenance capabilities. Other factors include life expectancy and maintenance accessibility.

A.2 Key and Overlooked TCO Factors

In addition to the upfront capital cost, the resounding common element of TCO was maintenance costs, which in most cases translates into rates and charges to the tenant airlines. Another was lack of redundancy within the BHS that results in a spike in operational costs when a failure occurs. One particular concern raised by an airport is the marked increase in spare parts costs due to lack of availability over this past year due to the pandemic. However, the majority of airport respondents echoed the fact that they rarely have the luxury of evaluating TCO at the onset of a project due to upfront budget constraints. One concern raised by a particular Original Equipment Manufacturer (OEM) was the ability to offer enhancements to a BHS that are rarely capitalized upon by the airport either because the designer was not aware of it and did not put it into the design, or because it increased Capital Expenditures (CAPEX) despite projected Operating Expenses (OPEX) savings.

Most interviewees agreed that oft-overlooked TCO considerations include cost for ground handling vs. BHS automation, technological obsolescence of upper-level controls, third-party contractors for operations (bag jam clearing, manual encoding, manual handling of oversize items, etc.), costs associated with missed or lost bags, system outages, and proper commissioning.

A.3 Procurement Processes Used

There was an acknowledgment by nearly all interviewees that design-build (DB) Progressive DB or Construction Manager At-Risk (CMAR) is becoming more and more of a trend, vs. design-bid-build (DBB). One airline noted that it was DBB and low-bid win that resulted in multiple vendors, multiple software platforms, and no commonality across systems. Another airline noted it is not so much the cost but that the fundamentals are addressed. With DB, this airline interviewee felt they have more control and can also achieve variety. Respondents also believe that DB tends to have a little more accountability, and in many cases, shifts risk from the owner to the contractor. Many airport representatives believe involving the BHS OEM upfront spurns innovation and ultimately a better product. However, in many cases, airports' flexibility to use different procurement methodologies is more restrictive depending on airport structure (city-owned, county, airport authority, etc.).

Public-Private Partnerships (PPP) and Design Assist (DA) were also mentioned, but experience was lacking by most interviewees.

A.4 Mitigating Risk and Cost

Airline representatives tend to agree that with a DB approach it is beneficial to have a design consultant onboard to oversee and manage the process while using an OEM for the design has been able to mitigate the risk. But having a good upfront baseline design or performance specification upfront is extremely beneficial, as well as requirements of uniformity between projects to mitigate overall program and components inconsistencies, according to airport sources.

Another airport noted the benefits of having a steering committee or project management team during the design phase, especially, if DB is being used, to bring everyone to the table - the designer, constructor, airport & airline representatives, and third-party operator (if not in-house). This airport noted that during a recent renovation project, there were voices that were not at the table, and they identified issues after construction. In other words, having the operators in the room can be invaluable to the design process, and all parties involved in designing, building, operating, maintaining, and paying should be engaged.

A few airports noted the importance of commissioning in the overall process of mitigating operational risk, especially when making connections with upstream or downstream portions of existing BHS. Others noted the need for redundancy within the system as a mitigation tool.

A.5 Importance of CAPEX vs. OPEX

The starkest contrast found between conventional wisdom and the airports/airlines responses was that, for the most part, the primary focus is on up-front CAPEX. One airline bluntly stated that the overall maintenance costs are not considered when procuring a new BHS, as they are funded from separate sources. Another airline mentioned the need to balance the two to have more capital dollars later, since their business model does not allow OPEX to be considered an investment. Most airport respondents similarly stated that since OPEX is treated differently, procurement of BHS projects typically follows a lowest costly CAPEX model. However, two airports noted the flaw in this strategy in the past and will certainly look for a balance in the future; one indicated that, based on past experiences and surprises in hidden operational costs, going forward they will tend to lean more toward OPEX when developing a system. Different thinking on the concept came from international entities where the airports operated under more of a self-sustainment model.

A.6 KPIs

The majority of the Key Performance Indicators (KPIs) referenced by respondents directly correlate to monitoring and reducing Missed Bag Rates (MBRs) to the airlines. Typical statistics include bag tracking/read rates, jam statistics and response times, lost bag rate, and downtime. Some airlines are attempting to track return on investment, focusing on cost per bag going through the system with respect to yearly maintenance costs. One airport noted a key maintenance objective of 80% planned/preventive and 20% reactive.

From an O&M's perspective, their ability to maintain uptime, which is typically a KPI for maintenance contracts, is using predictive analytics to closely monitor operational status, including such factors as excessive vibration or heat generation from motors.

A.7 Impacts of Quality Components / Equipment

All interviewees stressed the importance of quality components and the effect on longevity of the BHS, ease of maintenance, etc., but there is a threshold for impact on CAPEX. For state-run airports, justification for higher quality is sometimes onerous and requires base and add-alternate bids. Bringing the maintenance provider into the specification development early is essential, according to one airport.

A.8 Energy Consumption & Conservation

Only one U.S. airport interviewed is tracking BHS energy consumption, San Francisco International Airport, and they are only tracking energy consumption on the new Individual Carrier System (ICS). The biggest hurdle presented by interviewees is the ability to meter the motor control panels individually from the other airport systems. In some cases, the cost of electricity is minimal and is dispersed to the tenants through lease agreements and rates & charges. The consensus among those interviewed was that energy savings is more of an emotional vs. quantifiable endeavor. Nonetheless, airports and airlines are beginning to pursue using more energy efficient drive packages for their conveying systems, including Permanent Magnet Motors (PMMs) and Variable Frequency Drives (VFDs) on a more widespread basis.

A.9 Influence of Funding Source

The majority of BHS funding in the U.S. comes from municipal bonds and Passenger Facility Charges (PFCs) when airport funded. Funding from the Transportation Security Administration (TSA) is no longer the wellspring it once was. For the past few years and the foreseeable future, TSA will likely only fund projects replacing technologically obsolete Explosives Detection System (EDS) units or inline Checked Baggage Inspection Systems (CBIS) that are replacing standalone systems. The source of the funding is very influential, according to airports. Payback period and interest rates play a large part in the capital investment strategy. Internationally, it is a different story; many airports are self-funded and therefor have more control over how to spend their money. One international airport uses an airport improvement fee that goes back to projects. They also have rates and fees and development opportunities on airport property. And since they are akin to a non-profit organization, they do not have shareholders or pay out dividends, so the revenue goes back into the infrastructure.

A.10 Passenger Experience

From an airline perspective, most of the customer experience comes from surveys and most often relates to whether their bags arrive, and within a reasonable amount of time to the claim device. This has been further scrutinized as compliance with IATA Resolution 753 has been rolled out. Only in a few cases has customer feedback directly correlated to a capital improvement project, typically in the baggage claim hall.

Airports, on the other hand, appear to me more intentional about managing customer expectations. Many have internal customer relationship management groups that follow social media closely. They work very closely with the airlines when negative feedback is received regarding baggage. But most respondents indicate that applying a dollar value to the customer experience baggage-wise (other than the cost to return a lost bag) is difficult to quantify.

A.11 Emerging Technologies

ICS was touted as the most promising technology, but many acknowledged it is not a "one size fits all" solution and is most applicable to greenfield installations and applicable on an airport-wide basis. Another up-and-coming technology was Self-Service Bag Drops (SSBD), which aids not only in personnel savings but also adds the promising feature of touchless technology in a post-pandemic world. Advanced energy-efficient motors (such as PMMs) as discussed previously were also mentioned as promising.

Blockchain technology and implementation were discussed as a potential future application to BHS. Further research was conducted and discussed below.

A.12 Redundancy

As discussed previously, redundancy was a resounding priority amongst interviewees, especially in the context of achieving positive KPIs. Also, difficult to quantify monetarily in relation to TCO (other than CAPEX), numerous respondents provided anecdotal horror stories of system downtime due to single points of failure within the BHS.

A.13 Appendix A Acronyms

BHS	Baggage Handling System
CAPEX	Capital Expenditures
CBIS	Checked Baggage Inspection System
CMAR	Construction Manager At-Risk
DA	Design Assist
DBB	Design-Bid-Build
EDS	Explosive Detection System
GC	General Contractor
ICS	Individual Carrier System
KPI	Key Performance Indicator
MBR	Missed Bag rate
OEM	Original Equipment Manufacturer

OPEX	Operating Expenses
O&M	Operations and Maintenance
PFC	Passenger Facility Charge
PMM	Permanent Magnet Motor
PPP	Public-Private Partnerships
SSBD	Self-Service Bag Drop
SME	Subject Matter Experts
TCO	Total Cost of Ownership
VFD	Variable Frequency Drive

Appendix B Case Studies

B.1 Case Study #1: PGDS Submittal Cost Challenges

B.1.1 Process Challenges

Since the publication of the first version of the Planning Guidelines and Design Standards (PGDS) in 2007, Checked Baggage Inspection System (CBIS) design projects in the United States have had to comply with a host of requirements for both specific design attributes of a CBIS and the detailed nuances of each design submittal stage. Each step entails establishment and confirmation of equipment quantities and requires the development of a host of specific design documentation not typically required for procurement of non-CBIS BHS projects. In many cases, design teams or Original Equipment Manufacturers (OEMs) have struggled in adequately preparing these design packages. Since 2015, over 40% of TSA design submittal packages have been rejected, requiring revision and resubmittal. As a result of the subsequent delays to the project design schedule, additional costs are likely to be incurred by design teams, Program Management Organizations (PMOs), General Contractors (GCs), and airport administration.

B.1.2 Detailed Rejection

Rates: Each phase of design runs its own risk of rejection due to varying levels of complexity. Table B-1 below indicates the comparative rejection rate by design phase since 2015, according to TSA:

Table B-1. Rejection Rate for Initial Submissions

Submission Rejection Rate at Each Design Phase – Initial Submittals 2015-2021				
Pre-Design	**Schematic Design**	**30% Detailed Design**	**70% Detailed Design**	**100% Detailed Design**
39%	7%	19%	11%	70%

While some Integrated Local Design Teams ILDTs will attempt to save time in design schedules by requesting a variance to combine submittals (pre-design and schematic, for example), the results are staggeringly skewed toward rejection, as shown in Table B-2 below.

Table B-2. Rejection Rate for Combined Submissions

Submission Rejection Rate at Each Design Phase – Combined Submittals 2015-2021			
Pre-Design/ Schematic Design	**Schematic Design/ 30% Detailed Design**	**Pre-Design/ 100% Detailed Design***	**30% Detailed/ 100% Detailed Design***
64%	20%	100%	100%

*Only applicable to recapitalization projects

Furthermore, even resubmitted packages run the risk of rejection for lacking information or poor Quality Assurance/Quality Control (QA/QC). Table B-3 shows the rejection rate by phase for resubmittals.

Table B-3. Rejection Rates for Resubmittals (Revision 1 only)

Resubmittals (R1 only)								
Pre-Design R1	Schematic Design R1	Pre-Design/ Schematic Design R1	30% Detailed Design R1	Schematic Design/ 30% Detailed Design R1	70% Detailed Design R1	100% Detailed Design R1	Pre-Design/ 100% Detailed Design* R1	30% Detailed/ 100% Detailed Design* R1
23%	0%	25%	0%	0%	25%	15%	0%	0%

B.1.3 Cost-Related Impacts

Design Fees: Airports rely on the expertise of the ILDT, whether comprising a BHS design consultant, an OEM, or both. Design costs are typically estimated based on the hours required to produce a quality package and rarely include enough contingency to cover resubmittal. Other trades (architectural; Mechanical, Electrical, and Plumbing [MEP]; structural; etc.) not experienced with TSA submittal packages rarely account for the time and effort required for resubmittals and are thus not included in their price. A rising trend over the past few years entails the inclusion of a specialty consultant on the ILDT adept at preparing TSA submittal packages to preempt rejections, the cost of which is more than adequately covered by potential redesign/resubmittal costs.

Schedule: Schedule delays and requested compression are commonplace during the airport terminal facility design process. Very little margin for error or delay is available for "hiccups" experienced during the TSA submittal process. To mitigate this, ILDTs may sometimes commence the next phase of design immediately following the submittal of the previous phase without waiting for TSA's disposition of the package. Unless the design package has been thoroughly reviewed internally through a detailed QA/QC process by a team with TSA submittal experience, this is risky and may result in substantial rework should the submittal require revision, or worst case, significant design changes. This delay in schedule not only impacts the design team but also results in added PMO and GC costs. Furthermore, if construction is delayed as a result, the date of beneficial use (DBU) and subsequent 5-year growth forecast (DBU+5) could be skewed so much that additional Explosive Detection System (EDS) equipment is required, thus impacting the design.

B.1.4 Project examples

Below are four example airport projects that experienced the impact of added costs and schedule delays associated with revising and resubmitting CBIS design packages on the total upfront soft costs of a CBIS project. Each example highlights typical reasons for rejected submittals and offers best practices for preparing and submitting design documentation. The examples are from four different FAA airport categories and four distinct design phases.

B.1.4.1 Airport A (Medium Hub; CAT I; 6 EDS CBIS; design-build procurement)

The pre-design submittal for this new CBIS project was rejected by the TSA twice due to conflicting and missing information in the Alternatives Analysis Report (AAR). These issues could have been resolved with a more thorough internal review of the report to ensure that the PGDS guidelines had been met. The design also changed from an Individual Carrier System (ICS) solution to a traditional conveyor solution after the initial pre-design package was submitted to TSA. This major change in design led to delays and confusion for both the ILDT and TSA. Approval of pre-design submission typically takes 17-20 business days; Airport A's pre-design package was finally approved roughly 9 months after the initial rejection. Table B-4 shows the pre-design approval timeline for this project.

Table B-4. Airport A Submittal Approval Timeline

Airport A Submittal Approval Timeline	
Initial pre-design submitted	Month 0
Initial pre-design rejection letter received from TSA	Month 1
Pre-design R1 submitted	Month 4
Pre-design R1 rejection letter received from TSA	Month 5
Pre-design R2 submitted	Month 8
Pre-design R2 acceptance letter received from TSA	Month 9
TOTAL # DAYS TO APPROVE PRE-DESIGN	287 DAYS

The following problems with both the initial pre-design submittal and the subsequent resubmittal were identified as reasons for the rejections:

- Initial pre-design submittal issues
  - No preferred alternative was identified in the AAR.
  - The base bag demand assumptions differed greatly from the Government-Furnished Information (GFI) data.
  - The growth rates used in the calculations did not match rates published in the Federal Aviation Administration's (FAA's) Terminal Area Forecast (TAF) for the design timeframe.
  - Supporting data for equipment calculations was missing.
- Pre-design R1 submittal issues
  - No explanation was given for how the current-day flight schedule was modified to align with the GFI.
  - Conflicting base bag rates were shown throughout the report.
  - A future flight schedule was referenced multiple times but was not applicable to the report.
  - The report referenced multiple flight schedules.
  - Conflicting EDS throughputs were shown throughout the report.
  - Arrival profile information was missing for several airlines.
  - The provided flight schedules did not include all PGDS required information.
  - No RFV was submitted for reduced EDS throughput for alternate conveyance technology.
  - Conflicting EDS requirements were shown throughout the report.
  - Rough order magnitude (ROM) costs did not accurately depict the cost difference between alternate conveyance technology and traditional conveyor.
  - Conflicting oversize bag rates were used throughout the report.
  - The alternate conveyance technology alternative was identified as the preferred alternative, but much of the design criteria was focused on conventional conveyor.

The lessons learned from the pre-design submittal experience are numerous and apply to nearly all CBIS design projects:

- Baseline bag rates, whether from GFI or from a flight schedule, should be clearly defined.
- Any deviation from TAF growth rates should be submitted as an RFV.
- All supporting data for equipment calculations should be provided and the report should be checked for conflicts in the data.
- Only include pertinent data in the report to avoid confusion.
- The preferred alternative solution should be selected carefully, and every attempt made to keep this solution moving forward. Changing from ICS to traditional conveyor caused confusion and delays.

B.1.4.2 Airport B (Large Hub; CAT X; 8 EDS CBIS; design-build procurement)

The schematic design submittal for this new CBIS project was rejected despite only receiving three overall comments during the design review. This design utilized a split-CBIS configuration due to the space constraints and design requirements set forth by the owner. The TSA rejected the initial submittal, questioning how passenger flow balance in the ticketing lobby would be managed to ensure that the volume of bags would be evenly distributed to each CBIS. A Technical Interchange Meeting (TIM) was held to explain to TSA how the Owner-applied passenger flow management system would work and to ensure that this system met the requirements for the resubmittal. The schematic design package was approved roughly two months after the initial rejection. Table B-5 shows the schematic design approval timeline for this project.

Table B-5. Airport B Submittal Approval Timeline

Airport B Submittal Approval Timeline	
Initial schematic design submitted	Month 0
Initial schematic design rejection letter received from TSA	Month 1
TIM held with TSA	Month 3
Schematic design R1 submitted	Month 4
Schematic design R1 acceptance letter received from TSA	Month 5
TOTAL # DAYS TO APPROVE SCHEMATIC DESIGN	125 DAYS

The following problems with the initial schematic design submittal were identified as reasons for the rejection:

- The report did not clearly identify how the balance between the east and west pods would be kept near 50% as was assumed in the equipment calculations.
- No, Further justification was needed for providing the additional EDS machine required for the split-CBIS configuration versus a single CBIS.

The following lessons can be learned from the schematic design submittal experience:

- When a split-CBIS configuration is utilized, the bag demand between the two pods needs to be clearly defined. Altering this balance can impact equipment counts.
- Any new technologies that can impact the TSA should be explained in detail so that the TSA understands how the technologies will be implemented and how they will impact the CBIS. In this case, the passenger flow management system needed to be explained to provide an understanding of how the bag demand would be split between the two segregated CBIS matrices.
- The design criteria requirements set forth by the client may not always align with the PGDS requirements, especially concerning redundancy and capacity. These design requirements need to be outlined in the BDR to avoid confusion. Any RFVs required due to these requirements should be prepared and submitted prior to the design package submittal to TSA.

B.1.4.3 Airport C (Non-Hub; CAT III; 2 EDS CBIS; design-bid-build procurement)

The 30% design submittal for this new CBIS project submittal was rejected due to missing information and calculation errors that could have been avoided by thoroughly reviewing and double-checking the submittal before submittal to TSA. The calculation errors had to do with TSA equipment quantities, and TSA rejected the submittal in part due to the uncertainty in what those quantities would be. The 30% submittal was approved approximately 3 weeks after the initial rejection. Table B-6 shows the 30% design approval timeline for this project.

Table B-6. Airport C Submittal Approval Timeline

Airport C Submittal Approval Timeline	
Initial 30% design submitted	Month 0
Initial 30% design rejection letter received from TSA	Month 2
30%R1 design submitted	Month 2
30%R1 design acceptance letter received from TSA	Month 3
TOTAL # DAYS TO APPROVE 30% DESIGN	81 DAYS

The following problems with the 30% submittal were identified as reasons for the rejection:

- The Basis of Design (BDR) contained multiple blank pages, resulting in a substantial portion of necessary information missing from the submittal. The schematic design BDR also contained blank pages, and this had not been resolved in the 30% submittal. This resulted in a carryover of open comments from the schematic design level that could not be closed at the 30% level.
- Calculations for both EDS and Baggage Inspection Station (BIS) quantities were performed incorrectly; therefore, the equipment quantities that TSA would need to provide to the airport were not clear.

The following lessons can be learned from the 30% design submittal experience:

- All design documents should be reviewed carefully before submitting to TSA to ensure all information is present, consistent, legible, and meets the requirements for the design level in question as outlined in the most current version of the PGDS.
- Calculations should be double-checked for any errors. All formulas and calculations should be clearly shown to ensure TSA's confidence in equipment quantities. The TSA generally will not approve submittals to move on to more detailed levels of design if equipment quantities are in question.

B.1.4.4 Airport D (Small Hub; CAT II; 2 EDS CBIS; design-bid-build procurement)

This airport's CBIS design called for a mini in-line configuration, and the airport submitted an RFV to combine the 30% and 100% submittals. TSA approved the RFV, meaning the airport only had a single design level for which to submit and obtain approval (combined 30%/100%). However, because all design items need to be addressed properly and thoroughly in accordance with the PGDS at the 100% design level, 100% designs are often rejected because there are frequently at least a few outstanding non-compliant items that remain in the design. This was the case with this airport project – the combined 30%/100% submittal was rejected because the TSA review team found some minor items in the design that needed to be addressed before allowing the airport to move on to construction.

Upon receipt of the resubmitted design, TSA found additional items still outstanding. These were deemed to be "quick-fix" items, so TSA requested that the ILDT update and resubmit the documents in question without formally rejecting the design.

The combined 30%/100% design was approved approximately two months after the initial rejection. Table B-7 shows the combined 30%/100% design approval timeline for this project.

Table B-7. Airport D Submittal Approval Timeline

Airport D Submittal Approval Timeline	
Initial combined 30%/100% design submitted	Month 0
Initial combined 30%/100% design rejection letter received from TSA	Month 1
Combined 30%/100%R1 design submitted	Month 2
Updated design documents submitted to TSA	Month 3
Combined 30%/100%R1 design acceptance letter received from TSA	Month 4
TOTAL # DAYS TO APPROVE COMBINED 30%/100% DESIGN	110 DAYS

B.1.5 Summary

As mentioned in Appendix C, the PGDS is continually being modified to ensure the utmost in safe, optimal, efficient, and cost-effective screening solutions that meet the needs of the traveling public. Each step in the design submittal process entails establishment and confirmation of equipment quantities and requires the development of a host of specific design documentation not necessarily required for non-CBIS BHS projects that do not directly impact TSA. ILDTs and OEM teams are encouraged to include members with subject matter expertise with TSA design submittal experience to mitigate the impact of added costs and schedule delays associated with revising and resubmitting CBIS design packages.

B.2 Case Study #2: ICS vs. Conventional Conveyor

B.2.1 Introduction

This report focuses on the savings in capital expenditures, construction, operational maintenance, and energy consumption related to the areas noted above compared between ICS and conventional systems. A present worth Return on Investment (ROI) analysis with the cost of additional EDS machines and the savings related to the non-EDS-related costs are compared for medium- and high-volume BHSs. For the remainder of this report, a 3+1 conventional system is referred to as a medium-volume BHS, and a 6+2 system is referred to as a high-volume BHS.

While it is understood that the TSA pays for screening equipment and associated security personnel directly in the U.S., the surrounding infrastructure and associated operations and maintenance costs are borne by the airport. It is important to understand the entire cost burden which is presented herein.

For this analysis, a standard interest of 6% and inflation rate of 2% are used. The actual interest rate, accounting for the rate of inflation, is calculated to be 3.93%.

B.2.2 Capital Expenditure

The following capital costs related to the equipment and the installation are included in the analysis:

- EDS machines
- On-screen resolution (OSR) stations
- BISs
- Conveyors belts
- Baggage handling equipment
- TSA staffing in the CBRA
- Inbound baggage handling

B.2.2.1 EDS machines

B.2.2.1.1 EDS Throughput

The throughput of the CTX 9800 EDS is computed per PGDS v7.0 guidelines. The CTX-9800 was chosen for this analysis because it is the only EDS unit currently in use with ICS totes. As per the data provided in PGDS v7.0 (2020, 3), the EDS machine belt speed is assumed to be 39.5 feet per minute (fpm). Calculation of the throughput of the CTX machines assumes a standard mix of international and domestic bags.

- **Conventional Conveyor Design**: The data provided in PGDS v7.0 shows the average length of a domestic bag as 29.3 inches and the average length of international bags as 30.2 inches, both with a 12-inch tail-to-head spacing. The EDS machine throughput in a conventional system at 95% efficiency is 652 bags per hour.
- **ICS Design**: The ICS uses totes of a fixed notional length, so the throughput is independent of the percentage of international bags. Since 45-inch totes transport the bags, the ICS has less throughput compared to a conventional system. The throughput of the EDS machine in an ICS environment is 510 bags per hour assuming an 8-inch spacing between the trays.

Table B-8 compares EDS throughput in a conventional versus an ICS design.

Table B-8. Throughput of CTX 9800 - Conventional Conveyor and ICS Designs

Design	Bag/Tray Length	EDS Machine Throughput
Conventional	Domestic bags: 29.3 inches International bags: 30.2 inches	652 bph
ICS	All bags: 45 inches (tray length)	510 bph

B.2.2.1.2 EDS Machine Requirement

- **Conventional Design**: This analysis assumes that the bag demand of the conventional baggage system is equivalent to three non-redundant EDS machines for a medium-volume CBIS and 6 non-redundant machines for a high-volume system.
- **ICS Design**: The medium-volume system with the throughput of EDS machines at 510 bags per hour will require four non-redundant machines. A high-volume system will require eight non-redundant EDS machines.

EDS Machine Redundancy: PGDS v7.0 recommends one additional machine per EDS machine grouping. An EDS machine grouping is defined as a set of EDS machines fed by a single mainline.

- **Conventional Design**: The typical speed of a conventional conveyor system is 240 fpm. Assuming head-to-head spacing of seven feet between bags, the mainline volume is expected to be 1,800 bags per hour. Therefore, a medium-volume CBIS with three non-redundant machines will require a single mainline, and therefore one additional EDS machine is needed for redundancy. A high-volume system with six EDS machines will require two additional EDS machines for redundancy.
- **ICS Design**: The speed of an ICS mainline is 450 fpm and with head-to-head spacing of seven feet between totes, the capacity of a single mainline in an ICS is approximately 3,850 bags. A medium-volume ICS with four non-redundant machines will require one mainline, and a high-volume ICS with eight non-redundant machines will require two mainlines. Therefore, a medium-volume ICS will require one additional EDS machine for redundancy and a high-volume ICS will require two additional EDS machines for redundancy.

EDS Quantity: Table B-9 shows the total number of EDS machines required for the two systems under the medium and high-volume scenarios.

Table B-9. EDS Unit Cost Example

Design	Bag Volume	EDS Machine Throughput	Total # EDS
Conventional	Medium	652 bph	4
	High	652 bph	8
ICS	Medium	520 bph	5
	High	520 bph	10

EDS Unit Cost: Table B-10 shows typical equipment costs associated with the CTX9800 machine and ancillary equipment. This data was provided by Smiths Detection (formerly Morpho Detection LLC) for use in a 2017 TSA PGDS study, adjusted for inflation for 2022.

Table B-10. Cost of CTX9800s and Auxiliary Ancillary Equipment

Item	Cost
CTX 9800 EDS	$1,568,600
Multiple Network Server for 8 EDS	$189,750

EDS Installation, Integration, Testing, and Multiplex Network Installation	$345,725
Master Control Station for OSR Review	$6,199
Total Cost	**$2,110,273**

Present Worth of EDS Machine Installations: The useful life of an EDS machine is 15 years (PGDS 2020, 11). Therefore, a second installation is necessary to complete the CBIS life span of 20 years; the second installation will be used for the remaining 5 years. The present worth of the first and second installation of the EDS machines is as follows:

$$PV_{EDS\,machines} = \left[1 + \left\{\frac{1-(1+r)^{-5}}{1-\ (1+r)^{-15}}\right\}\right] x\ C_{EDS\,machines} x\ N_{EDS\,machines}$$

where $PV_{EDS\,machines}$ is the present worth of the capital expenditure for EDS machines and auxiliary equipment, C_{EDS} is the cost per CTX9800 DSi machine including auxiliary equipment, N_{EDS} is the number of EDS machines, and r is the actual interest rate using a nominal interest rate of 6% and an inflation rate of 2%.

Comparison of the Present Worth of EDS Machine Installations: A comparison of the present worth of EDS machine installations between conventional conveyor and ICS designs is shown in Table B-11.

Table B-11.Comparison of Present Worth of EDS Machine Installations

Design	Bag Volume	Total # EDS	Present Worth of EDS Machine Installation
Conventional	Medium	4	$11,811,022
	High	8	$23,622,045
ICS	Medium	5	$14,763,778
	High	10	$29,527,556

B.2.2.2 OSR Stations

Number of OSR Stations Required: The number of OSR stations depends on the number of non-redundant EDS machines, the throughput of each, and the false alarm rate. TSA-provided false alarm rates for domestic and international bags were used in the calculations. The OSR processing rate is provided in PGDS v7.0 (2020, 5). Table B-12 shows the number of OSR stations required.

Table B-12. Summary of Screening Equipment Requirements – OSR

Design	Bag Volume	EDS Machine Throughput	Total # OSR Stations
Conventional	Medium	652 bph	3
	High	652 bph	5
ICS	Medium	520 bph	3
	High	520 bph	5

Cost of OSR stations: The assumed cost of OSR equipment is shown in Table B-13.

Table B-13. Cost of OSR Station and Auxiliary Equipment

Item	Cost

Primary View Station (PVS)	$7,086
Secondary Viewing Station (SVS)	$7,718
SVS Mounting Kit	$2,151
Bar Code Reader	$2,025
Printer	$664
Total Cost	$19,644

Present Worth of OSR Stations: The life span of OSR stations is assumed to be 10 years as per the data provided in PGDS v7.0. Therefore, a second installation is necessary to complete the CBIS life span of 20 years; the second installation will be used for the remaining 10 years. The present worth of the first and second installation of the OSR stations is expressed as follows:

$$PV_{OSR\ Stations} = \left\{1 + \frac{1}{(1+r)^{10}}\right\}\ x\ (C_{OSR\ Stations}\ x\ N_{OSR\ Stations})$$

where $PV_{OSR\ Stations}$ is the present worth of the capital expenditure for OSR stations and auxiliary equipment, $C_{OSR\ Station}$ is the cost per OSR station including auxiliary equipment, $N_{OSR\ Stations}$ is the number of OSR stations, and r is the real interest rate.

Comparison of the Present Worth of OSR Stations: A comparison of the present worth of OSR station installation between the conventional conveyor and ICS designs is shown in Table B-14.

Table B-14. Comparison of Present Worth of OSR Stations

Design	Bag Volume	Total # OSR Stations	Present Worth of OSR Station Installation
Conventional	Medium	3	$145,580
	High	5	$242,634
ICS	Medium	3	$145,580
	High	5	$242,634

B.2.2.3 Bag Inspection Stations

BISs typically consist of two adjacent tables with auxiliary equipment and one shared ETD. The required number of BISs is computed using the alarm, out-of-gauge, oversize percentages, and the corresponding processing rates provided in PGDS v7.0 (2020, 5). Table B-15 shows the number of BISs required for the two systems.

Table B-15. Summary of Screening Equipment Requirement – BIS

Design	Bag Volume	Total # BIS
Conventional	Medium	17
	High	33
ICS	Medium	17
	High	32

BIS Cost: The cost of a pair of BISs is shown in Table B-16. This data was used in 2016 for a PGDS study and is adjusted for 2% inflation to estimate for 2022.

Table B-16. Cost of Bag Inspection Stations

Item	Cost
Pair of BISs	$22,852

Present Worth of Explosive Trace Detection (ETD) Stations: An ETD station consists of a pair of BISs. The life span of an ETD unit is assumed to be 10 years as per the data provided in PGDS v7.0. Therefore, a second installation is necessary to complete the CBIS life span of 20 years; the second installation will be used for the remaining 10 years. The present worth of the first and second installation of the ETD tables is expressed as follows:

$$PV_{ETD\ units} = \left\{1 + \frac{1}{(1+r)^{10}}\right\}\ x\ (C_{ETD\ units}\ x\ N_{ETD\ stations})$$

where $PV_{ETD\ units}$ is the present worth of the capital expenditure for ETD stations and auxiliary equipment, $C_{OSR\ Station}$ is the cost per ETD station including auxiliary equipment, $N_{ETD\ units}$ is the number of ETD stations, and r is the real interest rate.

Comparison of the Present Worth of the Cost of ETD Units: A comparison of the present worth of ETD units between the conventional conveyor and ICS designs is shown in Table B-17.

Table B-17. Comparison of Present Worth of ETD Station Installations

Design	Bag Volume	Total # ETD Stations	Present Worth of ETD Station Installation
Conventional	Medium	17	$429,402
	High	33	$808,286
ICS	Medium	17	$429,402
	High	32	$833,545

B.2.2.4 Conveyors, High-Speed Diverters (HSDs), and Vertical Sorter Units (VSUs)

Number of Conveyor Drives, Lengths, and CBIS Handling Equipment: The overall length of a conventional outbound system and the ICS equivalent is the same. The ICS will have additional length for inbound baggage handling. The number of drives in an ICS design is more than that of a conventional design, but the driven length of conveyor per drive is less than in a conventional conveyor design. Shorter conveyor sections in an ICS allow the system to have one tote per segment and for each segment to run only when there is a tote occupying that segment. The number of drives per linear feet of conveyor in each subsystem of an ICS was computed using the data provided in BEUMER Group's Conceptual Design Report (2015, 23). A summary of this data is shown in Table B-18.

Table B-18. Summary of Linear Feet per Drive in an ICS

Conveyor Subsystem	Length (ft)	Number of Drives	Linear Feet per Drive
CBIS (including Checked Baggage Resolution Area [CBRA])	1,441	274	5
Outbound system	6,571	702	9

Conveyor Subsystem	Length (ft)	Number of Drives	Linear Feet per Drive
Inbound system	1,456	288	5

Approximately 3.5 to 5 feet per drive is used for an equivalent ICS in this analysis. The number of conveyor drives and the lengths of conventional and ICS designs extracted from a sample conveyor manifest of medium and high-volume CBISs are shown in Table B-19 and Table B-20, respectively.

Table B-19. Conveyor Drives, Lengths, and BHS Equipment – Medium-Volume Systems

Item	Conventional Design		ICS Design	
	# Drives/ Units	Length (ft)	# Drives/ Units	Length (ft)
Ticket counter belts and curbside belts	45	1200	45	600 conv + 600 ICS
Security feed lines	6	100	18	100
Shunt lanes pre and post-EDS belts	56	200	70	250
High-speed diverters	14	-	15	-
Vertical sorter units	5	-	6	-
Clear lines between the VSU and main take away belt	20	128	48	170
OSR line between VSUs and main take away belt	20	96	35	120
Main take away clear line up to the most downstream divert point.	20	180	55	190
Main take away OSR line up to the Level 2 decision point	18	160	48	170
OSR clear line merging with the main clear line	10	100	30	100
OSR alarm line to the CBRA	6	64	18	64
Out-of-gauge bag line	10	100	30	100
Oversize bag line	10	100	30	100
Alarm line queue belts	29	116	30	116
Re-insert belts	13	110	30	110
Mainline belts feeding the makeup devices	40	1,150	300	1,150
Makeup devices	3	780	3	780
Inbound line	-	-	300	1,200
Total	**306**	**4,574**	**1,111**	**4,700 ICS + 600 Conv.**

Table B-20. Conveyor Drives, Lengths, and BHS Equipment – High-Volume Systems

Item	Conventional Design		ICS Design	
	# Drives/ Units	Length (ft)	# Drives/ Units	Length (ft)
Ticket counter belts and curbside belts	90	2,400	75	1200 conv. + 1200 ICS
Security feed lines	12	200	6	200
Shunt lanes pre and post-EDS belts	112	400	140	500
High-speed diverters	20	-	22	-
Vertical sorter units	9	-	11	-

Item	Conventional Design		ICS Design	
	# Drives/ Units	Length (ft)	# Drives/ Units	Length (ft)
Clear lines between the VSU and main take away belt	40	256	100	320
OSR line between VSUs and main take away belt	40	192	70	240
Main take away clear line up to the most downstream divert point.	40	360	110	380
Main take away OSR line up to the Level 2 decision point	18	320	96	340
OSR clear line merging with the main clear line	20	200	60	200
OSR alarm line to the CBRA	6	64	18	64
Out-of-gauge bag line	20	200	60	200
Oversize bag line	20	200	60	200
Alarm line queue belts	58	232	58	232
Re-insert belts	26	200	60	200
Mainline belts feeding the makeup devices	80	2,300	80	2,300
Makeup devices	6	1,560	500	1,560
Inbound line	-	-	600	2,400
Total	**582**	**9084**	**1,526**	**9,336 ICS + 1200 Conv.**

Cost of Conveyor Belts, and Mechanical and Electrical Installation Costs: The unit cost per foot of conveyor belts with the mechanical and electrical installation costs per drive used in this analysis are shown in Table B-21. These reflect actual costs incurred on a large BHS project in the United States completed in 2020.

Table B-21. Unit Cost for Mechanical and Electrical Installation of Conveyor Belts

Cost	Conventional System	ICS
Conveyor cost per linear foot	$2,140.04	$2,420.51
Conveyor mechanical installation, per linear foot	$5.99	$2.64
Conveyor electrical installation per drive	$13,788.50	$5,155.00
High-speed diverter per unit	$65,000	$65,000
Vertical sorter unit	$65,000	$65,000

Present Worth of Conveyor Material and Installation Costs: As per PGDS v7.0, the life span of the conveyor belts, the High-Speed Diverters (HSDs), and the VSUs is 20 years. This is the same as the life span of the entire baggage handling system. Therefore, the present worth of the conveyor and baggage handling equipment is the same as the cost of the initial installation.

Comparison of the Present Worth of the Cost of Conveyor, HSD, and VSU Installations: A comparison of the present worth of the cost of conveyor, HSD, and VSU installations between the conventional conveyor and ICS designs is shown in Table B-22.

Table B-22. Comparison of Present Worth of Conveyor Installations

Design	Bag Volume	Present Worth of Conveyor Installation
Conventional	Medium	$14,555,222
	High	$30,462,175

Design	Bag Volume	Present Worth of Conveyor Installation
ICS	Medium	$16,339,795
	High	$33,824,238

B.2.3 Operations and Maintenance Costs

The following are expenditures related to the operations and maintenance (O&M) of equipment:

- EDS maintenance cost
- Energy cost
- Cost of staffing the CBRA

B.2.3.1 EDS Machine Maintenance Cost

Annual EDS machine maintenance costs are assumed to be approximately 10% of purchase cost per unit. The initial purchase price typically includes two years of maintenance and therefore the maintenance cost of EDS machines starts two years after the installation.

Present Worth of Annual EDS Maintenance Cost: Useful time span of a CTX 9800 DSi machine is 15 years. The present worth of the maintenance cost of the EDS machines is computed as shown below. Since the cost of the EDS machine includes maintenance for the first two years, the first installation will require maintenance for 13 years. The second installation of the machines occurs after 15 years, and those machines will be used for the remaining five years. Out of those five years, maintenance cost will typically be covered for the first two years, under warranty. The present worth cost of the two installations of the EDS machines for the 20-year life span of the baggage system is as follows:

$$PV_{Maintenance\ Cost\ of\ EDS\ machines} = \left[\frac{1}{(1+r)^2}\ x \left\{\frac{(1+r)^{13}-1}{r(1+r)^{13}}\right\} + \frac{1}{(1+r)^{15}}\ x\ \frac{1}{(1+r)^2}\ x \left\{\frac{(1+r)^{3}-1}{r(1+r)^{3}}\right\}\right] x\ C_{Maintenance\ Cost\ per\ EDS\ machine}\ x\ N_{EDS\ machines}$$

where $PV_{Maintenance\ Cost\ of\ EDS\ machines}$ is the present value of the lifecycle maintenance costs for the EDS machines, $C_{Maintenance\ Cost\ per\ EDS\ machine}$ is the annual maintenance cost per EDS machine, $N_{EDS\ machines}$) is the number of EDS machines, and *r* is the real interest rate.

Comparison of the Present Worth of the Maintenance Cost of EDS Machines: A comparison of the present worth of the cost of maintaining the EDS machines between the conventional conveyor and ICS designs is shown in Table B-23.

Table B-23. Comparison of Present Worth of Maintenance Cost of EDS Machines

Design	Bag Volume	Present Worth of EDS Machine Maintenance Costs
Conventional	Medium	$9,055,598
	High	$18,111,195
ICS	Medium	$11,319,497
	High	$22,638,994

B.2.3.2 Conveyor Maintenance Costs

The data provided in the Conceptual Design Report, (BEUMER Group 2015, 28) was used to compute the O&M costs per foot of conveyor length for the conventional and ICS designs. The total conveyor length and the O&M costs per linear foot for the two systems are provided in Table B-24.

Table B-24. Annual Conveyor Maintenance Cost

Design	Bag Volume	Total Length (LF)	Annual O&M Cost per Foot	Annual O&M Cost
Conventional	Medium	4,574	$274	$1,253,276
	High	7,524	$274	$2,489,016
ICS	Medium	4,700 ICS + 600 conv.	4,700 @ $151 + 600 @ $274	$874,100
	High	9,336 ICS + 1,200 conv.	9,336 @ $151 + 1,200 @ $274	$1,738,536

Comparison of the Present Worth of Annual Conveyor Maintenance Cost: The present worth of annual maintenance cost is computed as follows:

$$PV_{Maintenance\ Cost\ of\ conveyors} = A_{Conveyor\ maintenance\ Cost}\ x\ \left\{\frac{(1+r)^{20}-1}{r(1+r)^{20}}\right\}$$

where $A_{Conveyor\ Maintenance\ Cost}$ is the annual cost of maintaining the conveyors.

A comparison of the present worth of the maintenance cost of the conveyors for the 20-year life span of the CBIS is shown in Table B-25.

Table B-25. Comparison of Present Worth of the Maintenance Cost of Conveyors

Design	Bag Volume	Present Worth of Conveyor Maintenance Costs
Conventional	Medium	$17,138,493
	High	$34,037,183
ICS	Medium	$11,953,279
	High	$23,774,402

B.2.3.3 Energy Costs

The energy costs provided in this section include the present worth of the expenditure related to the power consumption of the EDS machines and the power consumption related to conveyors, HSDs, and VSUs.

EDS Machine Power Consumption per Year: The energy consumption of CTX 9800 DSi is 10.3 kW. Like the assumptions made in the Conceptual Design Report (BEUMER Group 2015, 36), the EDS machines are assumed to operate for 20 hours per day for 365 days annually. This is equivalent to 75,190 kWh per EDS machine. The cost per kWh is assumed to be $0.1377 as per the data in the Conceptual Design Report (BEUMER Group 2015, 36). The annual cost of power consumption by the EDS machines computed using this data is shown in Table B-26.

Table B-26. Comparison of Annual EDS Machine Energy Consumption Costs

Design	Bag Volume	# EDS	Power Consumption in kWh	Annual Cost of EDS Power Consumption
Conventional	Medium	4	300,760	$41,415
	High	8	601,520	$82,829
ICS	Medium	5	375,950	$51,768
	High	10	751,900	$103,537

Comparison of the Present Worth of EDS Energy Cost: The present worth of the annual cost of power consumption for EDS machines for the 20-year life span of the CBIS is computed as follows.

$$PV_{Energy\ consumption\ cost\ of\ EDS\ machines} = A_{Energy\ consumption\ cost\ of\ EDS\ machines}\ x\ \left\{\frac{(1+r)^{20}-1}{r(1+r)^{20}}\right\}$$

where $A_{Energy\ consumption\ cost\ of\ EDS\ machines}$ is the annual cost of energy consumption cost of the EDS machines.

A comparison of the present worth of the EDS machine's annual energy consumption cost for the 20-year life span of the CBIS is shown in Table B-27.

Table B-27. Comparison of Present Worth of EDS Machine Energy Costs

Design	Bag Volume	Present Worth of EDS Power Consumption (20 years)
Conventional	Medium	$566,344
	High	$1,132,687
ICS	Medium	$707,929
	High	$1,415,859

Conveyor System Power Consumption per Year: The data in the Conceptual Design Report (BEUMER Group 2015, 28) is used to estimate the power consumption of the conventional and ICS conveyor sections per linear foot per year. This data is summarized in Table B-28. As shown in this table, the power consumption in an ICS design is significantly less as these conveyors run only when a tote is on the conveyor section. A conventional system typically allows the belts to run for 10 to 20 minutes after the last bag has cleared a conveyor section.

Table B-28. Power Consumption, Conventional and ICS Designs

Design	Power Consumption per Linear Foot per Year
Conventional	393 kWh
ICS	70 kWh

The total power consumed by the conveyor system in a medium- and high-volume baggage system is shown in Table B-29.

Table B-29. Comparison of Total Power Consumption – Conventional and ICS Designs

Design	Bag Volume	Conventional Belt (LF)	ICS Belt Length (LF)	Annual Power Consumption	Annual Cost @ $0.3117/kWh
Conventional	Medium	4,574	-	1,797,582 kWh	$247,527
	High	7,524	-	3,570,015 kWh	$491,591
ICS	Medium	600	5,900	564,800 kWh	$77,773
	High	1,200	9,336	1,125,120 kWh	$154,929

Comparison of the Present Worth of Conveyor Energy Consumption Cost: The present worth of the annual cost of power consumption by the conveyor system over the 20-year life span of the CBIS is computed as follows:

$$PV_{Energy\ consumption\ cost\ of\ conveyor\ system} = A_{Energy\ consumption\ cost\ of\ \text{the conveyor system}}\ x\ \left\{\frac{(1+r)^{20}-1}{r(1+r)^{20}}\right\}$$

where $A_{Energy\ consumption\ cost\ of\ the\ conveyor\ system}$ is the annual cost of energy consumption cost of the conveyor system.

The present worth of the energy consumption cost of the conveyor system is shown in Table B-30.

Table B-30. Comparison of Present Worth of Conveyor System Energy Cost

Design	Bag Volume	Present Worth of Conveyor System Power Consumption (20 years)
Conventional	Medium	$3,384,921
	High	$6,722,480
ICS	Medium	$1,063,542
	High	$2,118,648

B.2.3.4 Security Staffing Costs

The CBIS security screening personnel staffing costs presented in this study are similar to the analysis in the Conceptual Design Report (BEUMER Group 2015, 36). The number of agents required in the OSR room and CBRA is assumed to be the number of OSR and BIS positions computed to match the non-redundant EDS machine capacity. The number of agents required for OSR and CBRA screening is shown in Table 28. The average fully loaded burdened rates were received from the TSA's Operations Improvement Branch of the Office of Security Operations for the 2017 TSA PGDS study and were $69,200 per year. This rate, adjusted for inflation, is $77,790. The annual staffing cost for OSR and CBRA screening is shown in Table B-31.

Table B-31. TSA Staffing Requirement for OSR and CBRA Screening

Design	Bag Volume	# OSR Stations	# BISs	Requirements for OSR and CBRA Screening	
				# Agents	Annual Staffing Cost
Conventional	Medium	3	17	20	$1,555,800
	High	5	33	38	$2,956,020
ICS	Medium	3	17	20	$1,555,800

Design	Bag Volume	# OSR Stations	# BISs	Requirements for OSR and CBRA Screening	
				# Agents	Annual Staffing Cost
	High	5	32	37	$2,878,230

Comparison of the Present Worth of Staffing Cost for OSR and CBRA Screening: The present worth of the annual cost of staffing cost for OSR and CBRA screening over the 20-year life span of the CBIS is computed as follows:

$$PV_{Staffing\ cost\ for\ OSR\ and\ CBRA\ screening} = A_{Staffing\ cost\ for\ OSR\ and\ CBRA\ screening}\ x\ \left\{\frac{(1+r)^{20}-1}{r(1+r)^{20}}\right\}$$

where $A_{Staffing\ cost\ for\ OSR\ and\ CBRA\ screening}$ is the annual cost of staffing for OSR and CBRA screening.

Comparison of present worth of annual cost of OSR and CBRA staffing is shown in Table B-32.

Table B-32. Comparison of Present Worth of Annual Cost of OSR/CBRA Staffing

Design	Bag Volume	Present Worth of Staffing for OSR and CBRA Screening (20 years)
Conventional	Medium	$21,275,496
	High	$40,423,442
ICS	Medium	$21,275,496
	High	$39,359,667

B.2.3.5 Inbound Baggage Handling

In a conventional conveyor system, inbound baggage is transported via tug and cart from the aircraft to the terminal where it is either placed on a dedicated load belt for transport to its associated claim unit or placed on a direct feed flat plate claim unit. An ICS design allows the baggage to be loaded into totes at a remote location closer to plane side for delivery to the claim carousels. A bag loaded at any inbound load point can be delivered to any claim carousel through the ICS' inherent sortation processing. A comparison of the resources associated with inbound baggage handling is shown in Table 30. The common requirements such as the tug drive from the aircraft to the make-up carousels and the conventional conveyor belts feeding the bag claim devices are not included as the cost associated with these requirements are the same for the two designs.

The flow of bags along the ICS conveyors and the routes of tugs and carts from the make-up device to the bag claim area are shown in Figure B-1.

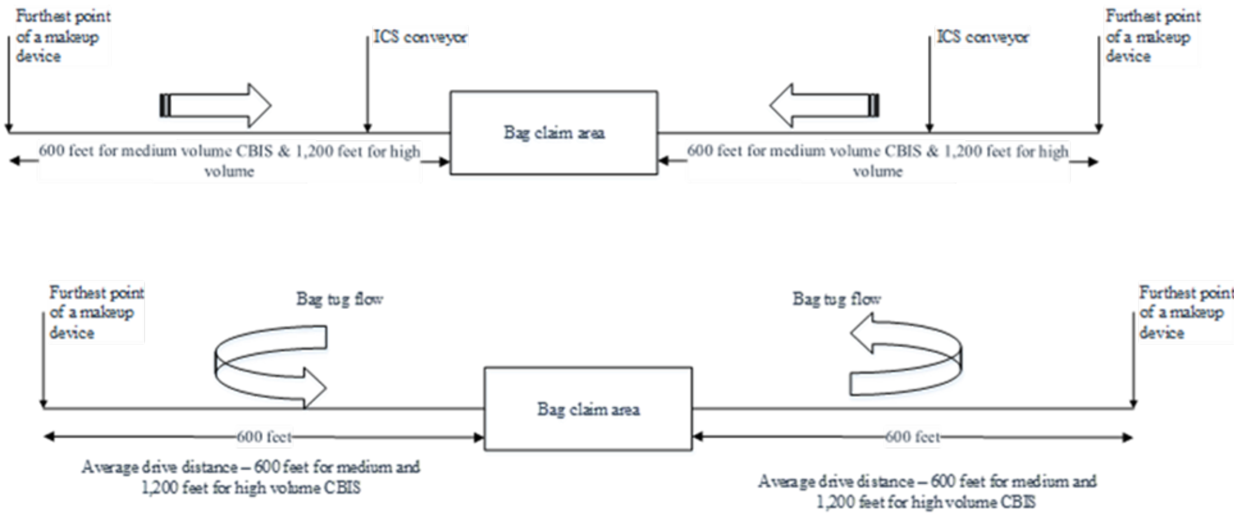

Figure B-1. Comparison of Inbound Bag Flow in Conventional and ICS Designs

A nominal length of the inbound conveyance in an ICS design spans 600 feet on either side from the location of the bag claim devices. For a high-volume system, this distance can be assumed to be 1,200 feet. Therefore, the total ICS conveyor length in a medium-volume system is 1,200 feet and a high-volume system will require 2,400 feet of ICS conveyor sections. These assumptions are shown in Table B-33.

Table B-33. Resources for Inbound Baggage Handling for Conventional and ICS Designs

Design	Bag Volume	Inbound Belts from Ramp Area		Average Round Trip Tug Drive Distance (LF)
		Linear Feet (LF)	Drives	
Conventional	Medium	-	-	600
	High	-	-	1,200
ICS	Medium	600	60	-
	High	1,200	120	-

Inbound Baggage Handling System Cost – Conventional Design

The following assumptions are used to compute the annual cost related to the use of tugs and carts to transport the bags from the make-up device area to the belts feeding the bag claim devices. As mentioned earlier, the cost related to transporting bags from the aircraft to the bag room is not included as it is common to both the conventional and ICS designs.

- The total number of arrivals for the medium-volume system is assumed to be 150.
- The high-volume system is assumed to have 300 inbound flights.
- The speed of the tug is assumed to be 5 mph.
- Like the data provided in the Conceptual Design Report (BEUMER Group 2015, 30), the hourly rate for the tug drivers is assumed to be $45 per hour.
- The system is assumed to operate 365 days a year.
- Each flight will use two tugs to deliver bags.

The annual cost of handling the inbound bags from the bag room to the belts feeding the bag claim devices is computed below.

Number of Tug Miles per Year: The number of miles travelled in inbound baggage handling per year is

$$\begin{aligned} &\mathit{Number\ of\ miles\ traveled} \\ &\quad = 2 * \mathit{number\ of\ flights\ per\ day} * \mathit{number\ of\ days\ per\ year} \\ &\quad * \mathit{average\ distance\ traveled\ per\ flight\ in\ miles} \end{aligned}$$

- Medium-volume system: For a high-volume baggage system, the total distance traveled per year is (2 x 150x 365 x 600) / 5,280 = 6,221 miles. Assuming that each flight requires two tugs per flight, the total tug travel distance = 2 x 6,221 = 12,442 miles.
- High-volume system: For a medium-volume baggage system, the total distance traveled per year is (2 x 300 x 365 x 1,200) / 5,280 = 24,884 miles. Assuming that each flight requires two tugs per flight, the total tug travel distance = 2 x 24,884 = 49,768 miles.

Annual Cost of Inbound Baggage Handling for a Conventional Design:

- Medium-volume system: The average speed of the tug is assumed to be 5 miles per hour and the hourly rate of a tug driver is set at $45 per hour. The cost of maintaining the tugs is $2 per mile per year. These assumptions are from the Conceptual Design Report (BEUMER Group 2015, 30). Therefore, the annual cost for the tug driver = ($12,442 / 5) x 45 = $ 111,988 per year. The annual cost of maintaining the tugs at $2 per mile per year is $ 2 x 12,442 = $24,884.
- High-volume system: The average speed of the tug is assumed to be 5 miles per hour and the hourly rate of a tug driver is set at $45 per hour. The cost of maintaining the tugs is $2 per mile per year. These assumptions are from the Conceptual Design Report (BEUMER Group 2015, 30). Therefore, the annual cost for the tug driver = ($49,768/5) x 45 = $ 447,912 per year. The annual cost to maintain the tugs at $2 per mile per year is $ 2 x 49,768 = $99,536.

The total annual cost of inbound baggage handling from make-up devices to bag claim for a conventional design is summarized in Table B-34.

Table B-34. Total Annual Cost of Inbound Baggage Handling from Make-up Devices to Bag Claim – Conventional Design

Bag Volume	# Flights	Average Distance per Flight (LF)	Annual Tug Driver Cost	Annual Cost to Maintain the Tugs	Total Annual Cost
Medium	150	300	$111,988	$24,884	$136,872
High	300	600	$447,912	$99,536	$547,488

B.2.4 Conclusion

B.2.4.1 Capital Costs

A comparison of the present worth of capital expenditure is shown in Table B-35, Table B-36, Figure B-2, and Figure B-3. As shown in the table and the graphs below, the present worth of the capital expenditure of an ICS design is higher than that of a conventional design. The higher cost is due to the additional EDS machines and the inbound conveyor system included in the ICS design.

Table B-35. Comparison of Present Worth of Capital Expenditure for a Medium-Volume System

Present Worth of Capital Expenditure – Medium-Volume System		
Cost Center	**Conventional Design**	**ICS Design**
EDS Machines	$11,811,022	$14,763,778
Conveyors	$14,555,222	$16,339,795
OSR Stations	$145,580	$145,580
ETD Tables	$429,402	$429,402
Total	**$26,941,227**	**$31,678,555**

Table B-36. Comparison of Present Worth of Capital Expenditure for a High-Volume System

Present Worth of Capital Expenditure – High-Volume System		
Cost Center	**Conventional Design**	**ICS Design**
EDS Machines	$23,622,045	$29,527,556
Conveyors	$30,462,175	$33,824,238
OSR Stations	$242,634	$291,161
ETD Tables	$808,286	$833,545
Total	**$55,135,139**	**$64,476,500**

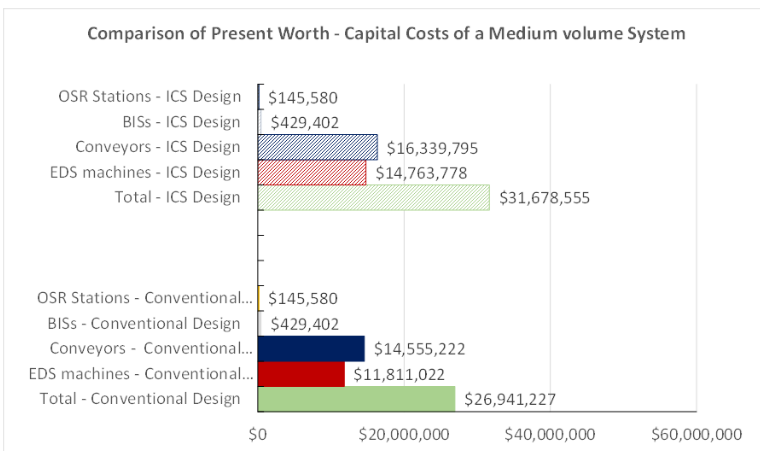

Figure B-2. Comparison of Present Worth of Capital Expenditure between Conventional and ICS Designs - Medium-Volume System

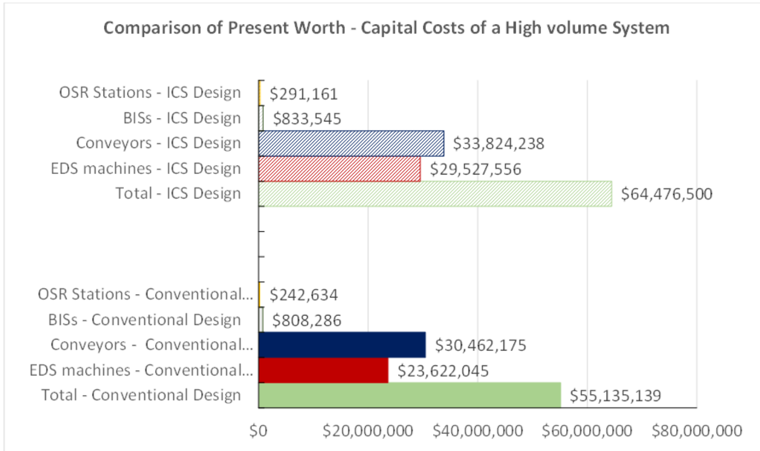

Figure B-3. Comparison of Present Worth of Capital Expenditure between Conventional and ICS Designs - High-Volume System

B.2.4.2 Maintenance Costs

A comparison of present worth of maintenance costs is shown in Table B-37, Table B-38, Figure B-4, and Figure B-5. As shown below, the maintenance cost related to the EDS machines is higher for the ICS design due to the additional machines. However, the cost of maintaining the conveyors is lower for the ICS design. The modular design simplifies the replacement and maintenance of the components in an ICS design.

Table B-37. Comparison of Present Worth of Maintenance Costs for a Medium-Volume System

Present Worth of Maintenance Costs – Medium-Volume System		
Cost Center	**Conventional Design**	**ICS Design**
EDS Machines	$9,055,598	$11,319,497
Conveyors	$17,138,493	$12,183,018
Total	**$26,194,091**	**$23,502,515**

Table B-38. Comparison of Present Worth of Maintenance Costs for a High-Volume System

Present Worth of Maintenance Costs – High-Volume System		
Cost Center	**Conventional Design**	**ICS Design**
EDS Machines	$18,111,195	$22,638,994
Conveyors	$34,037,183	$19,278,077
Total	**$52,148,378**	**$41,917,071**

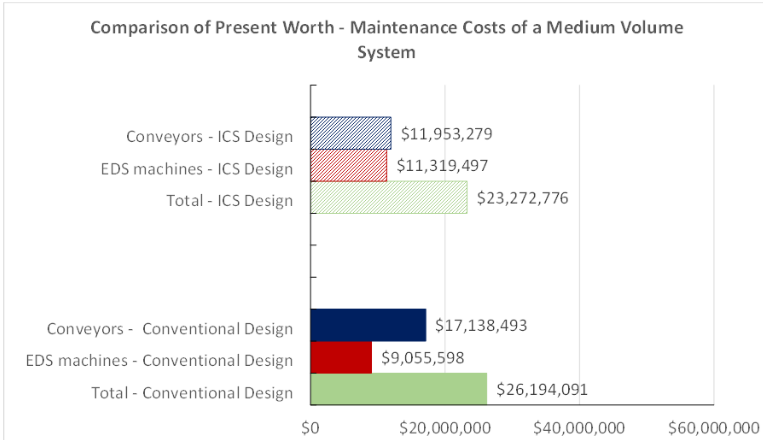

Figure B-4. Comparison of Present Worth of Maintenance Costs between Conventional and ICS designs – Medium-Volume System

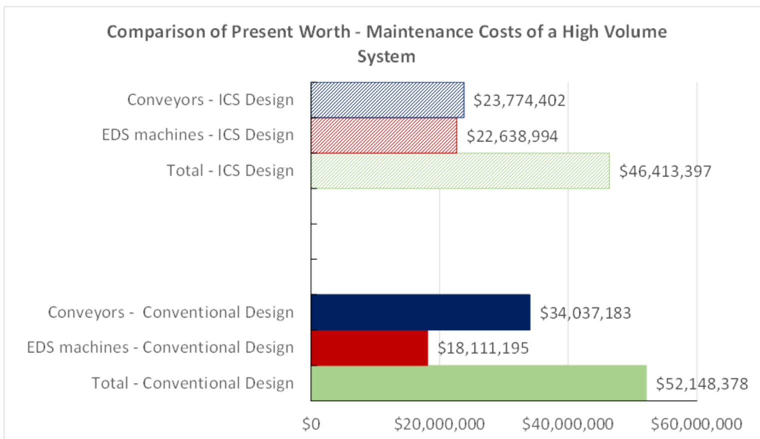

Figure B-5. Comparison of Present Worth of Maintenance Costs between Conventional and ICS Designs – High-Volume System

B.2.4.3 Energy Costs

The present worth of the costs related to energy consumption is shown in Table B-39, Table B-40, Figure B-6, and Figure B-7. As shown in the tables and figures below, the overall energy consumption of the ICS design is significantly lower than that of a conventional design. The energy consumption of the ICS conveyor system is significantly less than that of a conventional system. As mentioned before, the ICS conveyor sections run only when there is a tote occupying that section. Conventional sections continue to run for 10 to 20 minutes after a bag has cleared that section.

Table B-39. Comparison of Present Worth of Energy Costs for a Medium-Volume System

Present Worth of Energy Costs – Medium-Volume System		
Cost Center	**Conventional Design**	**ICS Design**
EDS Machines	$566,344	$707,929
Conveyors	$7,662,164	$1,760,406
Total	**$8,228,507**	**$2,468,335**

Table B-40. Comparison of Present Worth of Energy Costs for a High-Volume System

Present Worth of Energy Costs – High-Volume System		
Cost Center	**Conventional Design**	**ICS Design**
EDS Machines	$1,132,687	$1,415,859
Conveyors	$12,603,874	$2,785,618
Total	**$13,736,561**	**$4,201,477**

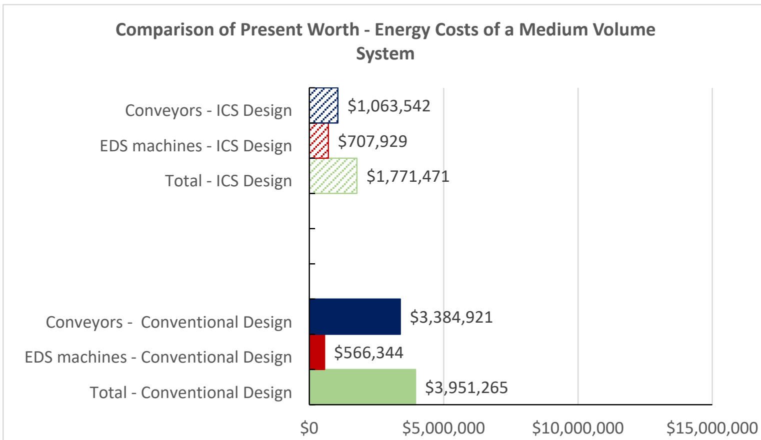

Figure B-6. Comparison of Present Worth of Energy Costs between Conventional and ICS Designs - Medium-Volume System

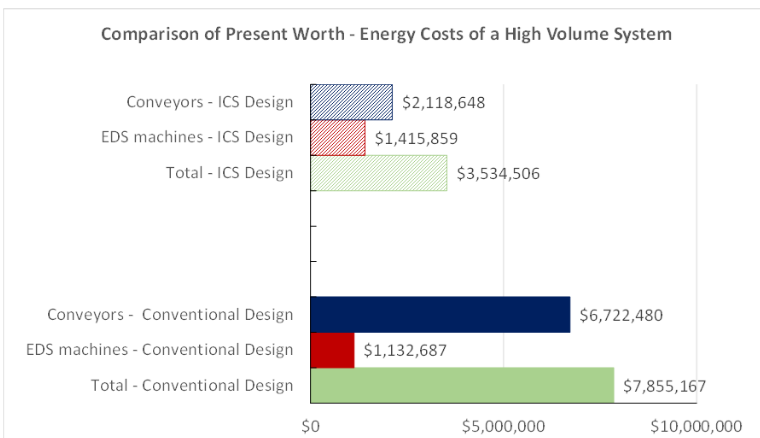

Figure B-7. Comparison of Present Worth of Energy Costs between Conventional and ICS Designs - High-Volume System

B.2.4.4 Inbound Baggage Handling

Inbound baggage cost is associated with conventional designs only. The ICS design will have a conveyor system that transports bags from the ramp area to the feeder belts of the bag claim devices. The present worth of the bag tug operations for a medium-volume system is $1,871,760, and for a high-volume system, the cost is $7,487,038.

B.2.4.5 CBRA Staffing Cost

One of the advantages of an ICS design is its accuracy in tracking bags as they move through the system. The percentage of totes carrying "lost in tracking" bags in an ICS is almost 0%. A conventional design will have approximately 2% of bags reach the CBRA as lost in tracking. However, these bags are re-inserted for re-screening and the time needed for re-insert is 30 to 60 seconds. Therefore, the difference in the staffing requirements for a conventional and ICS system is not significant.

B.2.4.6 Present Worth of Total Cost of Ownership

The present worth of the total cost of ownership of medium- and high-volume systems are compared for conventional and ICS designs. The results are shown in Table B-41, Table B-42, Figure B-8, and Figure B-9. As shown in the tables below, the difference in the total present worth cost of a high-volume system shows a bigger difference in favor of an ICS design than for a medium-volume system, but the total cost of ownership is lower for an ICS design in both cases. The major disadvantage of an ICS is the need for additional EDS machines to compensate for the lower throughput caused by the totes that are longer than a regular bag. This is overcome by the savings in the maintenance and energy consumption of the ICS conveyors.

Table B-41. Comparison of Present Worth of Total Cost of Ownership of a Medium-Volume System

Total Cost of Ownership – Medium-Volume System			
Cost Center	**Subsystem**	**Conventional Design**	**ICS Design**
Capital Cost	EDS Machines	$11,811,022	$14,763,778
	OSR Stations	$145,580	$145,580
	ETD Tables	$429,402	$429,402
	Conveyor System	$14,555,222	$16,339,795
	Total	**$26,941,227**	**$31,678,555**
Maintenance	EDS Maintenance	$9,055,598	$11,319,497
	Conveyor Maintenance	$17,138,493	$11,953,279
	Total	**$26,194,091**	**$23,272,776**
Energy	EDS Energy	$566,344	$707,929
	Conveyor Energy	$3,384,921	$1,063,542
	Total	**$3,951,265**	**$1,771,471**
Inbound Baggage Handling	Tug Operations	$1,871,760	
Security Screening Staffing	CBRA	$21,275,496	$21,275,496
Overall Total		**$80,233,838**	**$77,998,298**

Table B-42. Comparison of Present Worth of Total Cost of Ownership of a High-Volume System

Total Cost of Ownership – High-Volume System			
Cost Center	**Subsystem**	**Conventional Design**	**ICS Design**
Capital Cost	EDS Machines	$23,622,045	$29,527,556
	OSR Stations	$242,634	$291,161
	ETD Tables	$808,286	$833,545
	Conveyor System	$30,462,175	$37,452,259
	Total	**$55,135,139**	**$68,104,520**
Maintenance	EDS Maintenance	$18,111,195	$22,638,994
	Conveyor Maintenance	$28,191,960	$19,278,077

Total Cost of Ownership – High-Volume System			
Cost Center	**Subsystem**	**Conventional Design**	**ICS Design**
	Total	**$46,303,155**	**$41,917,071**
Energy	EDS Energy	$1,132,687	$1,415,859
	Conveyor Energy	$12,603,874	$2,785,618
	Total	**$13,736,561**	**$4,201,477**
Inbound Baggage Handling	Tug Operations	$7,487,038	
Security Screening Staffing	CBRA	$40,423,442	$39,359,667
Overall Total		**$163,085,336**	**$153,582,736**

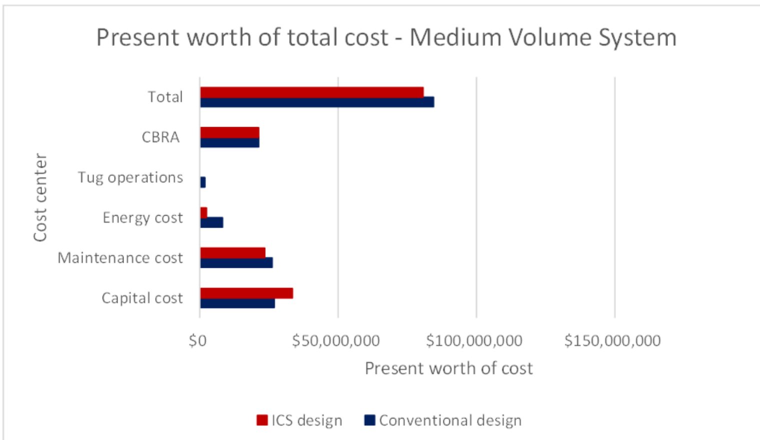

Figure B-8. Present Worth of Total Cost of Ownership of a Medium-Volume System

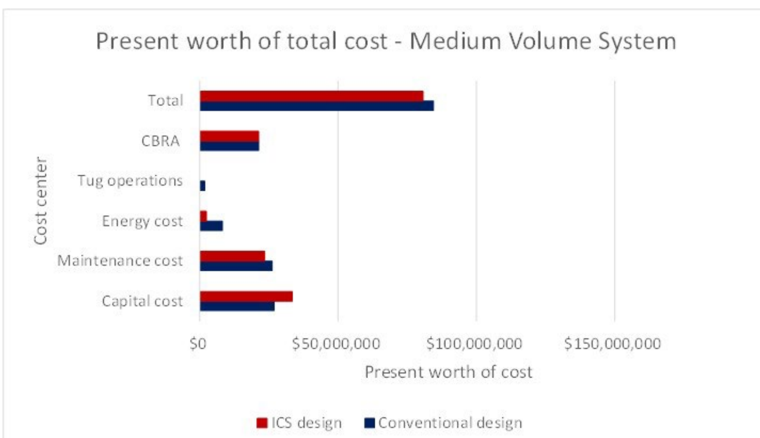

Figure B-9. Present Worth of Total Cost of Ownership of a High-Volume System

The return on investment (ROI) for the additional expenditure incurred by the ICS for the medium and high-volume systems is computed as follows:

<u>Medium volume system</u>

- Additional capital costs for an ICS - $4,737,328

- Annual equivalent of the savings in maintenance, energy cost, and tug operation cost in an ICS = $509,900
- The additional capital cost of the ICS in a medium volume system can be recovered in $4,737,328/$509,900 = 9.3 years.

High volume system

- Capital costs- Additional capital costs for an ICS - $12,969,381
- Annual savings in maintenance, energy cost, and tug operation cost in an ICS - $1,643,294
- The additional capital cost of the ICS in a high-volume system can be recovered in $12,895,595 /$1,643,294 = 7.8 years.

B.3 Case Study #3: BHS Motor efficiency

B.3.1 Purpose

The purpose of this study was to compile existing literature, data, and ongoing research on energy-efficient motors used in the Baggage Handling System of an airport. Information has been collected from both published and unpublished sources, and interviews have been conducted with experts from motor manufacturers.

The intended audience for the report is airport facility O&M staff, airport decision makers who select sustainability initiatives for implementation, and airport groups that establish sustainability policy.

B.3.2 Methodology

This report in this case study follows three steps.

- First, a review of the existing literature was completed to identify the practicality of Permanent Magnet Motors (PMMs) in terms of energy savings, efficiency, and return on investment. The literature review provides examples from existing projects to support the impact definition and analysis. Experts from motor manufactures were contacted and interviewed to augment the existing information base. From the reviewed documentation, we have developed theoretical data.
- Second, a controlled test and evaluation were conducted in a controlled laboratory.
- Third, testing was conducted in a live airport environment to verify the data.

The information obtained was organized in a systematic format by technology and cost-benefit.

B.3.3 Background

Government legislation: In the United States, the Energy Independence and Security Act (EISA) went into effect in 2010, mandating higher efficiency standards for general-purpose, three-phase ac industrial motors from 1 to 500 hp manufactured for domestic use. Europe has similar regulations. As of June 2011, the European Union (EU) only permits motors with efficiency class IE2 (International Efficiency), a boost in efficiency by up to 7% compared to older IEC designs. Since 2017, only motors with an IE3 efficiency class and greater are permitted in the EU.

From July 2021 motors between 0.75 kW and 1000 kW are required to meet a minimum efficiency class of IE3, the group of smaller motors from 0.12 kW to 0.75 kW minimum IE2. From 1 July 2023, motors between 75 kW and 200 kW will be required to meet the even higher efficiency class of IE4.

B.3.4 Introduction

Energy-efficient motors are becoming increasingly commonplace in the BHS industry. Energy efficiency is a quantifiable standard established by the International Electrotechnical Commission (IEC). The standard defines five IE (International Efficiency) classes for single-speed electric motors. These standards are related to efficiency, power output, and size for motors. The Standard established to measure efficiency classes for Alternating Current (AC) motors (the Standard IEC/EN 60034-30-1) was published by the IEC on March 6, 2014. This IEC standard is concerned with the global harmonization of energy efficiency classes for electric motors. Compared with IEC/EN 60034-30: 2008, it introduces IE4 efficiency performance class for electric motors.

B.3.4.1 IEC60034-30 Motor IE labelling scheme

The IE labelling scheme for motors is described in IEC60034-30-1 Rotating electrical machines – Part 30-1: Efficiency classes of line-operated AC motors (IE code). Although not published until March 2014, the efficiency levels contained within it had been used for many years by regulators and manufacturers. The tremendous benefit of this internationally recognized standard is that it gives motor buyers and sellers alike a straightforward way of describing how efficient a motor is. Very simply, the higher the IE number, the more efficient the motor.

B.3.4.2 Efficiency classes defined by IEC/EN 60034-30-1: 2014

The five IE efficiency classes for single-speed electric motors that are rated according to IEC 60034-30-2 and designed for operation on sinusoidal voltage are:

- Ultra-Premium efficiency IE5
- Super-Premium efficiency IE4
- Premium efficiency IE3
- High efficiency IE2
- Standard efficiency IE1

B.3.4.3 Classification Basis

The efficiency levels defined in IEC/EN 60034-30-1 are based on the low uncertainty test methods specified in IEC 60034-2-1, which has been updated to edition 2.0, 2014-06. The recently approved IEC 60034-30-2 defines efficiency classes for variable speed AC motors not covered in IEC 60034-30-1, including the PMM and synchronous reluctance motors that must be controlled by a frequency converter. This new standard also extends to an IE5 level.

It is worth mentioning that the standard IEC 60034-2-3 specifying the test methods for determining losses and efficiency of motors covered by IEC 60034-30-2 has not been approved.

B.3.4.4 Picking a motor type

Picking a motor type for your drivetrain is difficult. Each has advantages and disadvantages. Despite the AC induction motor being first developed more than 100 years ago, it is still viable thanks to efficiency and performance improvements in the 20th and 21st centuries. The permanent magnet motor is a relative newcomer but promises higher performance and generally lower weight.

The inherent efficiency of a permanent magnet motor is higher than an induction motor. Both motors use a three-phase design through fully optimized performance. Induction motors, however, were designed to work primarily at 60 Hz. As you increase the frequency, eddy current losses in induction motors will be far greater than in permanent magnet motors using powder metal technology.

The most enticing advantage of PMMs is that they sport higher efficiency, thanks to their simplified rotor. This efficiency is exceptional with small torque loads and can save many kWh of energy in these arrangements. These savings also increase with motor size, allowing PMMs to compete with conventional induction motors for high-speed, high-torque applications. The higher power density of PMMs combined with their high-speed capabilities and efficiency can give induction motors such as the classic squirrel cage and wound rotor motors a run for their money. They also tend to have a smaller footprint and are great for retrofitting older systems with newer, smaller, and more powerful PMMs. While more expensive than induction motors in their initial product cost, PMMs and their energy savings can realize a full return on investment in a little over two years. They are also synchronous, which allows them to work in applications where induction motors cannot.

- PMMs also run cooler than induction motors, which increases their reliability and lifespan.
- IE5 has a higher efficiency of over 6.6% on average over IE4 and 9.5% for IE3 motors.
- Lower inertia than IE3 and higher peak torque.
- Frame size reductions which translate to lower weight of the motor up to 50%.
- No rotor losses.

B.3.5 Theoretical Basis

B.3.5.1 Induction vs. Permanent Magnet Motor Efficiency

Consistent comparison of efficiency between different motor designs can be difficult. Efficiency depends to some degree on qualities of the drive-current waveform. It would be ideal to compare efficiency based on pure sinusoidal waveforms. Unfortunately, this is not possible because some designs always are driven from inverters whose outputs are generally characterized by a lot of high-frequency harmonics. With the switched-reluctance design, for example, the waveforms applied to the rotor are nowhere near sinusoidal.

Nevertheless, it is standard practice for efficiency comparisons to assume ideal current and voltage waveforms for each technology. This study used the efficiency charts from IEC, shown in Figure B-10.

Output	IE1 - 50HZ				IE2 - 50HZ				IE3 - 50HZ				IE4 - 50HZ			
KW	2 Poles	4 Poles	6 Poles	8 Poles	2 Poles	4 Poles	6 Poles	8 Poles	2 Poles	4 Poles	6 Poles	8 Poles	2 Poles	4 Poles	6 Poles	8 Poles
0,12	0,45	0,5	0,383	0,31	0,536	0,591	0,506	0,398	0,608	0,648	0,577	0,507	0,66	0,698	0,649	0,623
0,18	0,528	0,57	0,455	0,38	0,604	0,647	0,566	0,459	0,659	0,699	0,693	0,587	0,708	0,747	0,701	0,672
0,20	0,546	0,585	0,476	0,397	0,619	0,659	0,582	0,474	0,672	0,711	0,654	0,606	0,719	0,758	0,714	0,684
0,25	0,582	0,615	0,521	0,434	0,648	0,685	0,616	0,506	0,697	0,735	0,686	0,641	0,743	0,779	0,741	0,78
0,37	0,639	0,66	0,597	0,497	0,695	0,727	0,676	0,561	0,738	0,773	0,735	0,693	0,781	0,811	0,78	0,743
0,40	0,649	0,668	0,611	0,509	0,704	0,735	0,688	0,572	0,746	0,78	0,744	0,701	0,789	0,817	0,787	0,749
0,55	0,69	0,7	0,658	0,561	0,741	0,771	0,731	0,617	0,778	0,808	0,772	0,73	0,815	0,839	0,809	0,77
0,75	0,721	0,721	0,7	0,612	0,774	0,796	0,759	0,662	0,807	0,825	0,789	0,75	0,835	0,857	0,827	0,784
1,1	0,75	0,75	0,729	0,665	0,796	0,814	0,781	0,708	0,827	0,841	0,81	0,777	0,852	0,872	0,845	0,808
1,5	0,772	0,772	0,752	0,702	0,813	0,828	0,798	0,741	0,842	0,853	0,825	0,797	0,865	0,882	0,859	0,826
2,2	0,797	0,797	0,777	0,742	0,832	0,843	0,818	0,776	0,859	0,867	0,843	0,819	0,88	0,895	0,874	0,845
3	0,815	0,815	0,797	0,77	0,846	0,855	0,833	0,8	0,871	0,877	0,856	0,835	0,891	0,904	0,886	0,859
4	0,831	0,831	0,814	0,792	0,858	0,866	0,846	0,819	0,881	0,886	0,868	0,848	0,9	0,911	0,895	0,871
5,5	0,847	0,847	0,931	0,814	0,87	0,877	0,86	0,838	0,892	0,896	0,88	0,862	0,909	0,919	0,905	0,883
7,5	0,86	0,86	0,847	831	0,881	0,887	0,872	0,853	0,901	0,904	0,891	0,873	0,917	0,926	0,913	0,893
11	0,876	0,876	0,864	0,85	0,894	0,898	0,887	0,869	0,912	0,914	0,903	0,886	0,926	0,933	0,923	0,904
15	0,887	0,887	0,877	0,862	0,903	0,906	0,897	0,88	0,919	0,921	0,912	0,896	0,933	0,939	0,929	0,912
18,5	0,893	0,893	0,886	0,869	0,909	0,912	0,904	0,886	0,824	0,926	0,917	0,901	0,937	0,942	0,934	0,917
22	0,899	0,899	0,892	0,874	0,913	0,916	0,909	0,891	0,927	0,93	0,922	0,906	0,94	0,945	0,937	0,921
30	0,907	0,907	0,902	0,883	0,92	0,923	0,917	0,898	0,933	0,936	0,929	0,913	0,945	0,949	0,942	0,927
37	0,912	0,912	0,908	0,888	0,925	0,927	0,922	0,903	0,937	0,939	0,933	0,918	0,948	0,952	0,945	0,931
45	0,917	0,917	0,914	0,892	0,929	0,931	0,927	0,907	0,94	0,942	0,937	0,922	0,95	0,954	0,948	0,934
55	0,921	0,921	0,919	0,897	0,932	0,935	0,931	0,91	0,943	0,946	0,941	0,925	0,953	0,957	0,951	0,937
75	0,927	0,927	0,926	0,903	0,938	0,94	0,937	0,916	0,947	0,95	0,946	0,931	0,956	0,96	0,954	0,942
90	0,93	0,93	0,929	0,907	0,941	0,942	0,94	0,919	0,95	0,952	0,949	0,934	0,958	0,961	0,956	0,944
110	0,933	0,933	0,933	0,911	0,943	0,945	0,943	0,923	0,952	0,954	0,951	0,937	0,96	0,963	0,952	0,947
132	0,935	0,935	0,935	0,915	0,946	0,947	0,946	0,926	0,954	0,956	0,954	0,94	0,962	0,964	0,96	0,949
160	0,938	0,938	0,938	0,919	0,948	0,949	0,948	0,93	0,956	0,958	0,956	0,943	0,963	0,966	0,962	0,951
200	0,94	0,94	0,94	0,925	0,95	0,951	0,95	0,935	0,958	0,96	0,958	0,946	0,965	0,967	0,963	0,954
250	0,94	0,94	0,94	0,925	0,95	0,951	0,95	0,935	0,958	0,96	0,958	0,946	0,965	0,967	0,963	0,954
315	0,94	0,94	0,94	0,925	0,95	0,951	0,95	0,935	0,958	0,96	0,958	0,946	0,965	0,967	0,963	0,954
355	0,94	0,94	0,94	0,925	0,95	0,951	0,95	0,935	0,958	0,96	0,958	0,946	0,965	0,967	0,963	0,954
400	0,94	0,94	0,94	0,925	0,95	0,951	0,95	0,935	0,958	0,96	0,958	0,946	0,965	0,967	0,963	0,954
450	0,94	0,94	0,94	0,925	0,95	0,951	0,95	0,935	0,958	0,96	0,958	0,946	0,965	0,967	0,963	0,954
500-1000	0,94	0,94	0,94	0,925	0,95	0,951	0,95	0,935	0,958	0,96	0,958	0,946	0,965	0,967	0,963	0,954

Source: IEC [year]

Figure B-10. IEC Efficiency Chart

Motor efficiency formula:

Motor efficiency η is equal to the ratio between the output power P(o) in watts to input power P(i) in watts:

$\eta = Po / Pi$

Efficiency is always expressed in percentage $\% \eta = Po \times 100 / Pi$

B.3.5.2 Efficiency Cost Savings

To obtain an accurate calculation of how much you can save with an electric motor upgrade, an energy audit is the best option. However, the percentage savings can be estimated with Table B-43 below.

Table B-43. Cost Savings Comparison

Estimated Energy Savings from Increased Efficiency					
Operating Time 7,300 hours/year based on 20 hours/day					
1.5 kw (2 HP), 4 pole	**IE1**	**IE2**	**IE3**	**IE4**	**IE5**
Efficiency	77.20%	82.80%	85.30%	88.20%	94.80%
Energy Consumption kWh	14183	13224	12837	12414	11768
Energy Cost ($.09)	$1,276	$1,190	$1,155	$1,117	$1,059
		Compared to IE1	**Compared to IE1**	**Compared to IE1**	**Compared to IE1**
Annual Savings	kWh	959	1,346	1,769	2,415
Annual Savings	$	$86	$121	$159	$217
			Compared to IE2	**Compared to IE2**	**Compared to IE2**
Annual Savings			387	810	1,456
Annual Savings			$35	$73	$131
				Compared to IE3	**Compared to IE3**
Annual Savings				423	1,069
Annual Savings				$38	$96
					Compared to IE4
Annual Savings					646
Annual Savings					$58

B.3.5.3 Return On Investment (ROI)

We can deduce that if a motor that runs 20 hrs./per day with 85.3% efficiency (IE3) is replaced with a unit that has 94.8% (IE5) efficiency, the savings value is $96.00 annually per motor. Per one OEM, the cost difference between IE3 and IE5 is approximately $269. This means that the cost differential is made up in 2.8 years.

Table B-44. OEM Retail Motor Pricing

	2 HP	
	OEM 1	OEM 2
IE3	$438	$628
IE4	$548	$951
IE5	$685	$897

B.3.6 Laboratory Test

In May 2018, several independent tests were run in a laboratory setting to identify the energy-saving potential of the new IE-4 motors in comparison to IE-3 motors. To identify the energy-saving potential, five typical conveyors at VTC's Airport Integration Test Lab were selected to conduct a case study. Five conveyors, SS1-

02, SS1-03 (54-inch queues), SS1-04, SS1-05, and SS1-06 (36-inch queues) are straight conveyors with belt on traditional steel slider bed. The IE-4 motors were compared in terms of energy efficiency to the IE-3 motors.

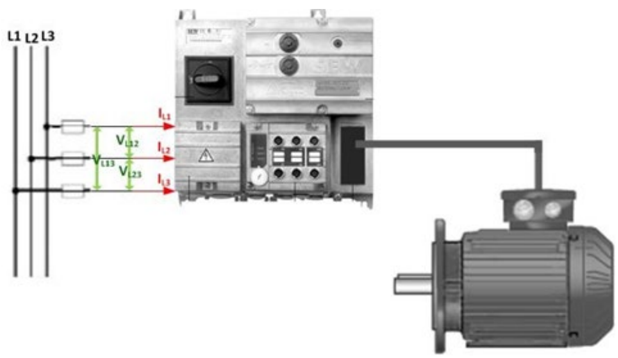

Figure B-11. Measurement of the original IE-3 setup

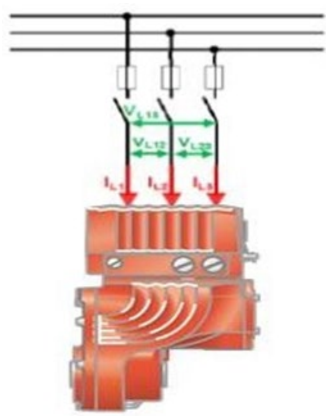

Figure B-12. Measurement of the IE-4 setup

B.3.6.1 Test Procedure

The IE-3 solution was tested by running each conveyor at the required setpoint speed and was controlled using a typical control system. The IE-4 testing was performed by commanding the units to run at the same setpoint speeds. The belt speeds at each setpoint were verified using a belt tachometer. The speed setpoints were set in feet per minute (fpm) utilizing the application configurator in the control unit. Each unit was run at three different speeds, both running without loads and with a simulated 100 lb. (45.35 kg) load. The three different speeds at which the tests were run were 40 fpm, 90 fpm, and 180 fpm.

B.3.6.2 Presentation of Data

The testing results were repeated in all five experiments. In all cases, the IE-4 motors consistently used much less energy in comparison to IE-3 motors. The energy savings were dependent on motor speed and loading changes. The results are summarized in Figure B-13.

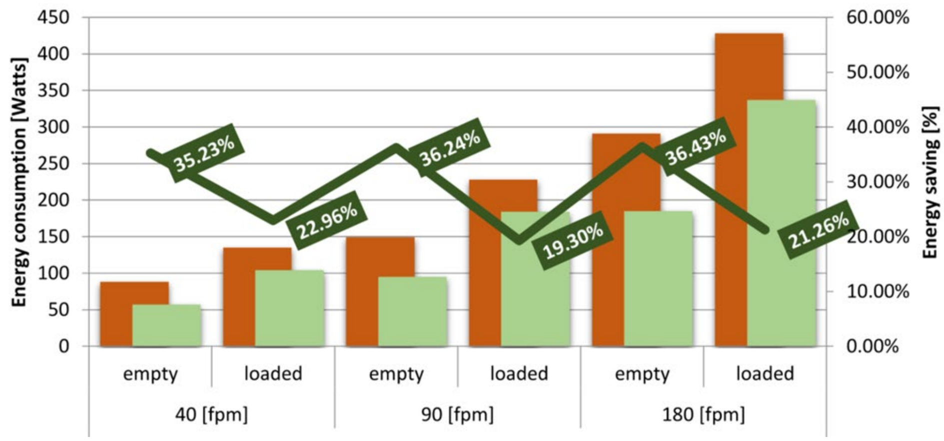

Figure B-13. Green – IE3& Orange- IE4

In all cases, the IE4 solution consistently used much less energy. The amount of savings is dependent on the motor speed and load factor. Table B-45 illustrates the measured relative energy savings % as a function of the loading or speed of the conveyor.

Table B-45. Relative energy savings

		Speed (fpm)		
		40	90	180
Load	100 lbs	28	25	27
	Empty	38	51	35
		Energy Savings Relative (%)		

B.3.6.3 Reasons to Determine Motor Load

Load factors and speeds can make a major impact to energy savings. The designers can make an impact on the overall system saving with the choice of motor size and gear ratio. The designer must determine the loads that a conveyor must be capable of carrying.

Most electric motors are designed to run at 50% to 100% of rated load. Maximum efficiency is usually near 75% of rated load. Thus, a 2-hp motor has an acceptable load range of 1 to 2 hp; peak efficiency is at 1.66 hp. A motor's efficiency tends to decrease dramatically below about 50% load. A motor is considered underloaded when it is in the range where efficiency drops significantly with decreasing load. Table B-45 shows that power factor tends to drop off sooner, but less steeply than efficiency, as load decreases.

PMM motors can be sized to normally be operating nearer their efficient operating duty point, as these motors can deliver 400% of normal load torque during start-up compared to 200% for asynchronous motor types. Hence the product sizing can be more directed at achieving efficient steady-state conditions rather than oversizing to meet start up torque requirements; this is probably the most significant cause of efficiency improvement.

For each conveyor unit tested, a simulated load profile was applied to calculate an estimated yearly energy savings. Overall, the IE4 efficiency rating solution resulted in total energy savings of 1340 kWh/$120.60 per year as indicated in Figure B-14.

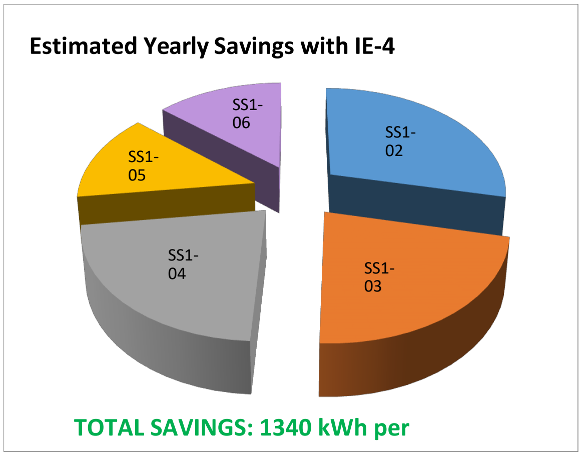

Figure B-14. Overall estimated energy savings using IE-4

Table B-46. Total Estimated Power Savings for all 5 Tested Units

Zone	IE3 power usage (Watts)	IE4 power usage (Watts)	Power Savings (Watts)	% Relative Savings	Estimated Yearly Savings (kWh)
SS1-02	286.5	212.8	73.8	25.7	382
SS1-03	197.0	139.5	57.5	29.2	298
SS1-04	207.7	150.4	57.3	27.6	297
SS1-05	186.3	151.6	34.7	18.6	180
SS1-06	103.9	68.5	35.4	34.1	183

B.3.7 Field Test

To demonstrate the calculation of energy cost saving, payback period, and life expectancy of motor compared to equivalent, a case study was started in a live airport environment, to compare an existing IE2 vs replacement IE4 motors. A baseline was set with the IE2 motors and then 1000 motors were replaced with IE4.

Currently, motors are being evaluated and compared in terms of lifetime energy savings, reducing the burden on any cooling systems and payback period.

*This study does not include the cost of removal of the old and installation of the new motors

*No allowance has been made for capital cost savings that are likely to be enjoyed due to simpler commissioning and lower capital installation/cabling costs for the IE4/5.

*No potential indirect benefits have been quantified such as:

- reduced manual handling costs for maintenance;
- longer possible asset life and lower maintenance and replacement costs from condition monitoring and condition-based maintenance planning;
- possible savings from avoiding the use of mechanical braking systems;
- possible other operational and maintenance savings from SCADA-based monitoring of the drive assembly such as emulation of plug and play, advanced prediction of failing motors, and use of this to stretch mean time between maintenance activities; and
- potential reduction in price as PMM technology becomes more widely used in this context.

B.3.7.1 Whole life cost analysis

Whole life cost is defined as the cost in use over the whole life of the asset including the initial capital costs, replacement costs, maintenance costs, and energy costs. The following are not included in the whole life analysis:

- This study does not include the cost of removal of the old and installation of the new motors
- No allowance has been made for capital cost savings that are likely to be enjoyed due to simpler commissioning and lower capital installation/cabling costs for the IE4/5.
- No potential indirect benefits have been quantified such as:
  - reduced manual handling costs for maintenance
  - longer possible asset life and lower maintenance and replacement costs from condition monitoring and condition-based maintenance planning
  - possible savings from avoiding the use of mechanical braking systems
  - possible other operational and maintenance savings from Supervisory Control and Data Acquisition (SCADA)-based monitoring of the drive assembly such as emulation of plug and play, advanced prediction of failing motors, and use of this to stretch mean time between maintenance activities
  - potential reduction in price as PMM technology becomes more widely used in this context

Table B-47 shows the whole-life costs and savings of IE2, IE4, and IE5 motors.

Table B-47. Whole Life Cost Savings

	IE2	IE4	IE5
Total Whole Life Costs Per Motor	$18,914	$12,710	N/A
Savings over IE2		$6.204	

At a lifetime savings of $6,204 per motor gained by installing IE4 motors instead of IE2 motors, a BHS with 1000 motors would equate to a $6,204,000 lifetime savings for the system. The purchase premium is more than recovered and a whole life cost saving of (30%) is achieved over 15 years of service compared with the IE2 technology. These savings are driven more by energy efficiency gains than any other factor.

B.3.7.2 Motor Upgrade Savings

Estimating the energy savings from a motor upgrade is determined by three main factors:

- The efficiency difference between the existing motor and the upgrade
- The operating schedule of the motor
- The local electricity cost per kWh

Lifetime energy savings from upgrading from IE2 motors to IE4 motors is shown in Table B-48

Table B-48. Lifetime Energy Savings

	IE2	IE4	IE5
Lifetime Electricity Cost	$11,100	$6,990	N/A
Savings over IE2		$4,110	

At a lifetime savings of $4,110 per motor, a BHS with 1000 motors would equate to a $4,110,000 savings. This performance was achieved assuming present-day energy pricing throughout, which accounts for over $4,110 of the whole-life costs for the PMM option and over 66% of the whole-life costs for all the options. It is a safe assumption that energy prices will continue to increase over the fifteen-year life cycle further increasing the energy price savings.

Although the capital costs are based on purchase costs rather than fully installed costs, there are no significant cost differences to impact the overall ranking through sensitivity analysis. It is noted that the installed costs would improve for the IE4 PMM option relative to the other options due to the reduced costs for cabling and commissioning. Likewise, the replacement and maintenance costs are relatively minor due to the robust running times for the motors, so there would not be any significant change from sensitivity analysis.

B.3.8 Conclusion

As described in this study, the dollar savings on upgrading motors to IE4/5 efficiency motors is variable. This study found that significant savings are probable upon upgrade and return on investment can be achieved in a period of 2.8 years.

As most of the cost savings achieved are through energy efficiency, with tested PMM being 39% more efficient than the worst performing technology from the IE2 test data, the anticipated future increases in energy costs will continue to dramatically increase the savings made in service.

Depending on motor size, electric utility rate, and duty cycle, designers can realize a full return on a certain PMM motor purchases in one year. PMM efficiency ratings are one to three indexes above NEMA Premium, which translates to 10% to 30% fewer losses than a conventional motor. Electricity is estimated to comprise approximately 95% to 97% of the total lifecycle cost of electric motors, so energy savings significantly reduce the total investment.

The results seem to indicate that energy-efficient motors can have a positive effect on efficiency and lead to a reduced carbon footprint. Other potential benefits may include longer service lives, longer bearing lives, lower heat output, less vibration and noise, and lower maintenance costs.

In short, due to their synchronous operation, PMM motors also offer better dynamic performance and speed-control precision — a benefit in high-inertia positioning applications. Although the power factor with a drive may not be as high as a motor-only induction machine, PMM motors generally provide higher power density due to higher magnetic flux. Therefore, more torque can be produced in each physical size, or equal torque produced in a smaller package. Finally, PMM motors generally operate more coolly than ac induction motors, resulting in longer bearing and insulation life.

The IE-5 Class of motors offers even more potential for cost and energy savings. Regarding their basic functionality, motors with efficiency class IE5+ are synchronous motors and are equipped with permanent magnets in the rotor package. These very high-efficiency motors allow for high energy savings, especially in the partial load and partial speed range. IE5+ motors are designed for operation with a frequency inverter. Due to their high efficiency, frequency inverters offer energy-saving advantages. From an efficiency point of view, the complete system must be considered. Frequency inverters have an efficiency of > 95%. By optimized processes, the use of inverters can offer energy-related advantages to the extent that they oppose the power loss of the individual device by a multiple by using speed control. A case study comparing a motor of this type to an earlier iteration or iterations is recommended. IE5 is relatively new, and a case study should be done in the future once IE5s are more prevalent.

B.4 Appendix B Acronyms

AAR	Alternatives Analysis Report
AC	Alternating Current
BIS	Baggage Inspection Station
BPH	Bags Per Hour
CBIS	Checked Baggage Inspection Systems
CBRA	Checked Baggage Resolution Area
DBU	Date of Beneficial Use
DRN	Design Review Notification
EDS	Explosive Detection System
EISA	Energy Independence and Security Act
ETD	Explosive Trace Detection
EU	European Union
FAA	Federal Aviation Administration
GC	General Contractor
GFI	Government-Furnished Information
HSD	High-Speed Diverter
ICS	Individual Carrier Systems
IE	International Efficiency (class)
IEC	International Electrotechnical Commission
ILDT	Integrated Local Design Team
LF	Linear Feet
O&M	Operations and Maintenance
OEM	Original Equipment Manufacturer
OSR	On-Screen Resolution
PGDS	Program Guidelines and Design Standards (for Checked Baggage Inspection Systems)
PMM	Permanent Magnet Motor

PMO	Program Management Office
QA/QC	Quality Assurance/Quality Control
ROI	Return on Investment
ROM	Rough Order of Magnitude
SCADA	Supervisory Control and Data Acquisition
SSI	Sensitive Security Information
TAF	Terminal Area Forecast
TIM	Technical Interchange Meeting

Appendix C PGDS Design Submittal Process

C.1 Coordination with TSA

When considering a new, optimized, or expanded Checked Baggage Inspection System (CBIS), it is important to begin discussions with TSA's Acquisition Program Management (APM) Planning Branch. Responsibilities for the CBIS design process for airports across the country are divvied up between Planning Branch Regional Planning Coordinators (RPCs) who track the CBIS design process from conceptualization through completion of 100% design, at which point the project is handed off to the corresponding Regional Deployment Coordinator (RDC) within APM's Deployment & Sustainment Division (DSD). The name and contact information for a particular airport's assigned RPC and RDC may be obtained from the airport's Federal Security Director (FSD).

Initial discussions should include a request for data extracted from the existing Explosive Detection System (EDS) units in terms of the current volumes of bags processed by each EDS unit over a defined period. This data is retrieved from the Field Data Recording System (FDRS) or Government Furnished Information (GFI) and may be compared to the airport's planning parameters.

Periodically special cases arise where full compliance with Program Guidelines and Design Standards (PGDS) requirements is difficult. It is important to determine if deviation, or variance, will be necessary or desired for the design of the CBIS. This may be achieved through the submission of a Request for Variance (RFV) to the RPC during the appropriate design stage. An RFV must be submitted before the design submittal to receive disposition in a timely fashion. Without an approved RFV for a particular deviation, the design submittal risks rejection, requiring revision and resubmittal, or the design phase may be put on hold pending receipt of an approved RFV. In most cases, TSA reviews and responds to RFVs within 2-3 business days. For special cases, it may be longer and require additional information from the Integrated Local Design Team (ILDT).

For special cases, such as implementation of new technology or unique planning parameters, the TSA makes available the scheduling of a Technical Interchange Meeting (TIM) where the ILDT may discuss design principles and challenges with the TSA engineers to determine if TSA is amenable to implementation of the special case and whether an RFV will be necessary. This also may be coordinated through the RPC.

C.2 Overview and Timeline

The TSA helps ensure that Transportation Security Equipment (TSE) and Transportation Security Officers (TSOs) will be used effectively and efficiently throughout the life of a CBIS, which is why CBIS design projects must be submitted to the TSA for approval. The TSA approves designs by reviewing them against the PGDS as the design progresses to ensure that the design meets TSA's standards and best practices.

To submit a CBIS design to TSA for review, airports should email documents or a link to access documents to CBTPlanning@tsa.dhs.gov to ensure timely receipt and review and copy the TSA Regional Planning Coordinator (RPC).

Design review submittals at all stages will have some similar requirements:

- All formulas and calculations should be clearly shown.
- Any document containing Sensitive Security Information (SSI) must be password-protected and contain all proper SSI markings.
- Submittal should state the applicable PGDS version.

As TSA performs the review of a design submittal, any deficiencies in meeting PGDS requirements found will be noted on a TSA design review comment spreadsheet. This document becomes the foundation of the review process: once TSA has completed a review, the airport's ILDT will respond to each comment in the spreadsheet and submit their responses with the next design submission. As the design progresses, TSA will close out comments as they are addressed. At the 100% design level, the airport will be allowed to move on to construction once all the open comments from TSA are addressed, verified, and closed out.

Once TSA completes the review of a design submittal, a Design Review Notification (DRN) meeting is held with the ILDT and the airport to discuss the findings of the review. The TSA design review comment spreadsheet forms the basis of the discussion – each open design review comment is reviewed during the meeting. At the conclusion of the meeting, the TSA RPC determines whether the design can progress to the next level.

The approximate review timelines (from initial design submission through DRN meeting) for each design level are as follows:

- Pre-design: 17-20 business days
- Schematic design: 17-20 business days
- 30% design: 27-30 business days
- 70% design: 22-25 business days
- 100% design: 17-20 business days

C.3 Documentation Required at Each Stage

New CBIS designs should be designed in accordance with the most current version of the PGDS, unless otherwise agreed to with TSA. All recapitalization projects (i.e., the replacement of aging or technologically obsolete EDS equipment) should be designed in accordance with the PGDS version with which the CBIS was originally designed to comply, at a minimum.

For any combined design submittals (e.g., pre-design/schematic design, 70%/100%, etc.), the submittal must include all documentation and requirements for both design stages. However, for any document that is required for both stages, only one document will be needed for the design submittal. For example, a Basis of Design Report (BDR) is a required document for all design stages except pre-design, but a combined 70%/100% submittal only requires one BDR report to be included with the submittal.

C.3.1 Pre-Design

The intent of the pre-design phase is to identify a preferred CBIS design through a process of evaluating various alternative designs. Baseline conditions and determination of estimated design-year baggage screening demand are also defined at this stage. TSA and the airport will agree on the preferred CBIS layout before moving on to the next design level.

Pre-Design Phase Deliverables (In-Line and Mini In-Line CBIS) include the following:

- Alternatives Analysis Report (AAR)
- Preliminary Contingency Plan (mini in-line designs only)

The AAR should include multiple alternative CBIS layouts with a description, basic layouts, and analysis of life cycle costs and other relevant criteria clearly explaining the airport's reasoning for their preferred alternative. Such relevant criteria can include:

- Customer level of service
- Effect on airport operations
- Economic considerations
- Design criteria (effect on existing facilities, ease of expansion, etc.)
- Ergonomic considerations.

The report should also detail the assumptions and methodology used to determine the design-year baggage screening demand with all calculations clearly shown.

The analysis presented in the report should make the preferred alternative clear. PGDS 7.0 (2020, section 5.7.2.3) states: "*Once the costs of all concept-level alternatives have been developed to include the full present value life cycle costs, alternatives shall be ranked based on present value life cycle costs and the lowest-cost alternative that meets all other requirements shall be selected as the preferred alternative.*"

C.3.2 Schematic Design

This phase is used to further refine the preferred alternative design selected in the pre-design phase.

Schematic Design Phase Deliverables (In-Line and Mini In-Line CBIS) include:

- Basis of Design Report that includes:
  - Detailed program requirements
  - Preferred EDS equipment make and model
  - High-level flow-based modeling assumptions and results
  - Preliminary concept plans
  - Contingency plan (mini in-line designs only)
  - Phasing and constructability technical memoranda
  - Rough Order of Magnitude (ROM) estimate of probable construction costs and Operations and Maintenance (O&M) costs
  - Stakeholder notification documentation
  - Preliminary project schedule
  - Environmental conditions compatibility assessment
- Written response to each TSA comment from previous design submittal (if applicable) using TSA comment spreadsheet

The AAR from the pre-design submittal serves as the foundation for the BDR for the schematic design. All information and calculations relating to the agreed-upon CBIS layout from the AAR should be included in the BDR and be further refined by including the elements listed in Table 2.

It is imperative that schematic design submittal clearly demonstrate exactly how much TSE, including EDSs, Baggage Inspection Stations (BISs), etc., will be needed in the Design Year (defined as Date of Beneficial Use [DBU]+5) before moving on to the detailed levels of design (30%, 70%, and 100%).

C.3.2.1 30% Design

30% Design Phase deliverables include:

- Updated Basis of Design Report
- Preliminary plans for all disciplines
- Cross sections
- Concept of operations
- Contingency plan (mini in-line designs only)
- Baggage and data flow charts
- Table of contents for CBIS
- Screening equipment installation guidelines references
- Outline of reporting capabilities
- National Environmental Policy Act (NEPA) form completion
- Stakeholder notification documentation
- 30% Current Working Estimate (CWE) and Life Cycle Cost Analysis (LCCA)
- Preliminary phasing schedule
- Conveyor manifest
- List of EDS equipment that will be decommissioned
- Written response to each TSA comment from previous design submittal (if applicable) using TSA comment spreadsheet

Preliminary plans should include all major elements and their elevations, any inclines/declines, proper conveyor labels, and the EDS removal path (also including vertical dimensions).

Preliminary phasing should be represented in the BDR, the preliminary plans, and the schedule:

- The BDR should include a section on phasing that gives a brief description of the state of the system in each phase.
- Preliminary plans should have a phasing section clearly showing the conveyor layout and Baggage Handling System (BHS)/EDS components at each phase of construction. The phases represented in the plans should correlate to the phasing as described in the BDR.
- A preliminary phasing schedule listing the anticipated start and end dates for each phase, along with other major activities.
- Note: ensure that phasing breakdowns are consistent among all documents. For example, if the plans break down the phasing into Phase 1, Phase 2A, Phase 2B, and Phase 3, the BDR and the schedule should use the same breakdown/numbering system.

A copy of the screening equipment installation guidelines should be included in the submittal. This can be obtained from the Original Equipment Manufacturer (OEM).

C.3.2.2 70% Design

The 70% design further refines and adds more detail to the design and documents submitted at the 30% design level.

Mini in-line CBIS designs and straight recapitalization projects do not need to submit a design at the 70% level, but all detailed design deliverables from this phase except for dynamic simulation are required at the 100% level.

70% Design Phase deliverables (in-line designs only) include:

- Updated Basis of Design Report
- 70% design drawings
- Cross sections
- Refinements to description of operations
- Refinements to Bag Time in System calculations
- Preliminary contingency plan
- 70% specifications
- Draft site-specific configuration management plan
- Stakeholder notification documentation
- 70% CWE and updated LCCE
- Refined phasing plan and schedule
- Conveyor manifest
- Updated EDS equipment list (to be decommissioned)
- Conveyor manifest
- Written response to each TSA comment from previous design submittal (if applicable) using TSA comment spreadsheet

The drawings submitted at 70% should include all trades in addition to BHS. Items such as catwalks, egress, E-stop zones, control station locations, and Master Control Panel (MCP) locations should be shown.

The preliminary contingency plan should thoroughly describe all instances of potential screening equipment failure, conveyor failure, power failure, and total system failure, and include the entity responsible for handling baggage and how until the system is restored to normal.

If any information on the EDSs to be decommissioned (if applicable to the project) was unknown at the 30% level, this should be updated in the EDS equipment list at the 70% level.

C.3.2.3 100% Design

At the 100% design level, all issues should be addressed, and all details should be shown and/or accounted for. Schedule milestones should be finalized, all previous concerns noted in the TSA design review comments should be addressed, and the drawing package should include all details and ensure information is consistent across all trades.

100% Design Phase deliverables (in-line designs only) include:

- Bid documents
- Final Basis of Design Report
- Final description of operations
- Final contingency plan
- Project specifications
- Final site-specific configuration management plan
- NEPA form confirmation
- Stakeholder notification documentation
- Final 100% CWE and updated LCCA
- Final phasing plan and schedule
- Updated (completed) EDS equipment list
- Updated conveyor manifest
- Written response to each TSA comment from previous design submittal using TSA comment spreadsheet

It is common for TSA to reject the first submittal of 100% design packages since a few items to be corrected are almost always found during the review. However, correcting such items usually only takes the ILDT a few days, and the turnaround time for TSA to review a resubmittal of a 100% design package is normally much shorter than that of any other design level.

C.4 Appendix C Acronyms

AAR	Alternatives Analysis Report
APM	Acquisition Program Management
BDR	Basis of Design Report
BHS	Baggage Handling System
BIS	Baggage Inspection Station
CBIS	Checked Baggage Inspection Systems
CWE	Current Working Estimate
DBU	Date of Beneficial Use
DRN	Design Review Notification
DSD	Deployment and Sustainment Division
EDS	Explosive Detection System
FDRS	Field Data Recording System
FSD	Federal Security Director
GFI	Government Furnished Information
ILDT	Integrated Local Design Team
LCCE	Life Cycle Cost Analysis
MCP	Master Control Panel
NEPA	National Environmental Policy Act
O&M	Operations and Maintenance
OEM	Original Equipment Manufacturer
PGDS	Program Guidelines and Design Standards (for Checked Baggage Inspection Systems)
RFV	Request for Variance
ROM	Rough Order of Magnitude

RPC	Regional Planning Coordinator
SSI	Sensitive Security Information
TIM	Technical Interchange Meeting
TSE	Transportation Security Equipment
TSO	Transportation Security Officer

Appendix D BHS TCO Decision Assist Toolkit

The Total Cost of Ownership for Baggage Handling Systems report provides a set of variables and considerations for stakeholders as they consider various aspects of TCO in the BHS context. Not all aspects of the BHS procurement and selection process may require the same level of stakeholder discussion and consideration. Some decisions might be predetermined, or options limited by internal or external factors, such as funding sources, state and local regulations, or facility limitations. The report was written with this thought in mind and organized to allow users to locate and delve into areas of particular interest or import to project decision-makers.

Similarly, the BHS TCO Decision Assist Toolkit is composed of separate topic areas that represent phases in BHS procurement and decision-making, including:

- BHS Design Considerations
- Project Procurement
- BHS Technology Selection
- OPEX Considerations

Each section is structured with a basic overview of the topic areas, opportunities, and tradeoffs associated with various decisions and the impact of each decision to the total cost of ownership of the BHS. Additionally, each section includes a list of suggested data points and metrics for users to gather to inform their discussions around a set of questions, broken down by subtopic. The questions are intended to facilitate discussions among stakeholders about the overall topic and surface considerations about how each decision fits into the broader context and longer-term outcomes.

These conversations are structured for a group discussion to include affected airlines, airport staff and leadership, and the O&M personnel. For more information on the importance of stakeholder engagement and how to establish a project governance structure, refer to section 2.4 of the report, titled The Impact of Stakeholder Engagement on TCO.

Due to the variability of facility configurations, funding and stakeholder priorities, and operational parameters, this tool cannot provide a definitive TCO calculation. Instead, the discussion prompts will provide a foundation for considering individual decision points through a TCO lens.