Ergonomic engineering solutions for airport baggage handling

Evaluating equipment, processes to reduce strain, injuries

By Ben Zavitz and Ming-Lun Lu

Baggage handling is a physical task in which employees manually handle baggage during several phases, from customer drop-off to loading an aircraft. Conveyors, tuggers and belt loaders transport baggage between locations, such as check-in counter to bag room and bag room to aircraft. Once at a location, employees must manually move baggage on and off the next piece of equipment.

As noted in a survey conducted by Lu, et al., (*Applied Ergonomics Journal*, 2018), the average weight of checked bags at a large U.S. airport was about 32 pounds, with approximately 3% of bags exceeding 50 pounds. Actual baggage weight varies significantly depending on the flight traffic and number of staff. In high travel seasons, a range from 15%-25% of bags weighing more than 50 pounds is common. It is estimated a baggage handler can lift up to 10,000 pounds per shift.

Among 19 industry sectors classified by the U.S. Bureau of Labor Statistics in 2019, transportation and warehousing had the second highest incidence rate (4.4%) of nonfatal occupational injuries and illnesses. The injury incidence rate (6.5%) for the air transportation sector was 1.1% greater than the second highest sector-based injury rate (4.4%). Of recordable injuries, overexertion or musculoskeletal injuries accounted for the majority. Several studies have shown that over half of baggage handlers report pain in the shoulders, knees and lower back.

The ergonomic risks from handling baggage at U.S. airlines have been studied by many groups, including the U.S. Occupational Safety and Health Administration (OSHA), National

Institute for Occupational Safety and Health (NIOSH), universities, European organizations and companies, and authors of this article. The conclusion is that the ergonomic risk of baggage handling ranges from low for light bags to very high for heavy bags. The individual risk varies depending on bag weight, vertical height and distance of the lift, hand reach from the lower back, trunk twisting/sideways bending, grip on load, frequency of handling, facility design, aircraft and the equipment used. Figure 1 illustrates how bag weight and frequency influence ergonomic risk (green is low risk, yellow is moderate risk, red is high risk and purple is very high risk).

Ben Zavitz's presentation at the 2019 Applied Ergonomics Conference showed a cumulative risk/damage as identified using the LiFFT (lifting fatigue failure tool) and RCRA (recommended cumulative rest allowance) methodologies from heavy bags can contribute to over 50% and as high as 83% of a lifting task risk, despite heavy lifts only being 25% of all lifts. The rest time needed to recover from handling heavy bags is not sufficient and adds to overall fatigue. Alireza Tafazzol, et al., in *International Journal of Occupational Safety and Ergonomics* (2016) found that 24% of baggage handlers have a revised NIOSH lifting equation (RNLE) cumulative frequency lifting index greater than 3.0, indicating very high risk. These studies indicate about a quarter of baggage handlers' manual handling work poses a high risk for back injuries.

To minimize risk, the most common ergonomic interventions for baggage handling primarily have been lift training and administrative and work practice controls. Specific examples include employee training on biomechanics and proper lifting techniques; job rotation between tasks of higher physical demands and ergonomic risk to those with lower risk; heavy bag tags to signal an employee to prepare and use proper techniques or get help; team lifts when lifting heavy objects (large bag, fish box or wheelchair, etc.); stretching and warming up prior to work and/or after breaks; and early symptom recognition and job coaching.

The effectiveness of the above interventions on reducing ergonomic risk and musculoskeletal disorder (MSD) injury rates have been limited. These results are consistent with an article by Richard W. Goggins, et al., in *Journal of Safety Research* (2008) that found interventions that rely

FIGURE 1

The weight factor

A look at the ergonomic risk of bag weight versus frequency (adopted from L. Oxley, D. Riley, S. Rapley *Health and Safety Executive Report*, 2009).

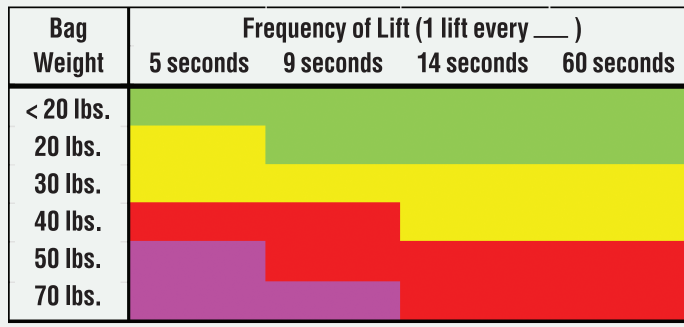


FIGURE 2

Injury impact

The effectiveness of ergonomic interventions (adopted from Richard W. Goggins, et al., *Journal of Safety Research*, 2008).

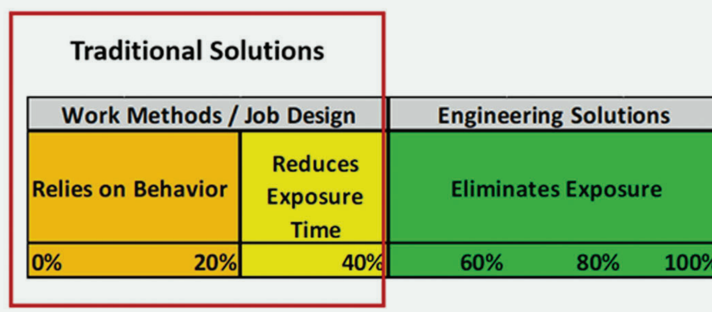


Photo by Ben Zavitz

Baggage conveyors can be either single pier, seen here, or double decker pier. Each has advantages and disadvantages.

on behaviors are less than 15% effective, with engineering solutions being the most effective with a 60-100 reduction of ergonomic risk (Figure 2 on Page 39).

To address the long-term ergonomic risks and associated MSDs, the air transportation industry needs to invest in engineering and equipment solutions that are effective in reducing ergonomic risk and injuries and improve operational efficiency. Below are examples of ergonomic equipment solutions for the bag room. In a future article, we will share solutions specific to the ramp and aircraft activities.

FIGURE 3

Solution matrix

The four categories in Marc G. Weinstein's ergonomics solution matrix are based on the complexity of the solution and the time necessary to implement. (adopted from by A.M. Dale, et al., *American Journal of Industrial Medicine*, 2017)

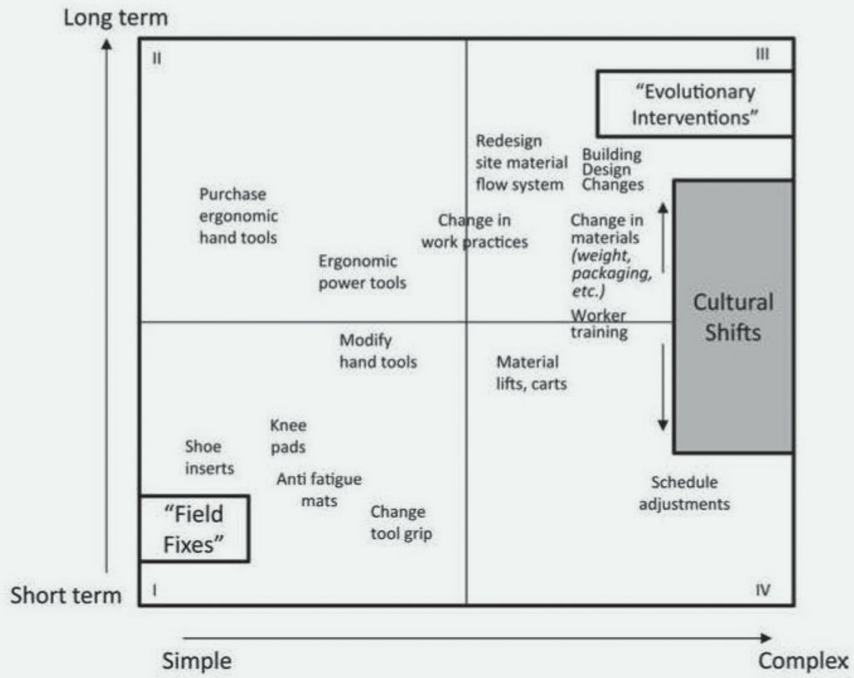


Photo courtesy of Indeva Group

An example of an overhead hoist hook design.

Bag room ergonomic engineering solutions

The bag room, or baggage makeup area, is where employees remove bags from the main handling system and load them into carts or containers to transport to the airplane by performing bending, reaching, pushing, pulling, lifting and carrying motions. There are numerous styles of bag room conveyors, including flat plate carousels, single pier belts, double decker pier belts, sloped carousel belts and oversized, each presenting unique ergonomic risks and challenges.

The ergonomic risks vary depending on the type and design of the conveyor (vertical heights, horizontal reaches, bollard protection.), size and weight of the bags and frequency of lifting. The primary body parts of concern are the back, shoulders and arms.

The two primary engineering solutions to reduce or eliminate the ergonomic risks in the bag room include conveyor design and baggage loaders and lift assists.

Design. The incorporation of ergonomic design guidelines and criteria into the design of the conveyor systems and baggage makeup areas is the first line of defense to reduce injury risk. In particular, the conveyor height, depth and conveyor/bollard protection are features to consider.

Height. Conveyors can be either single pier or double decker pier. Each has advantages and disadvantages. Single pier belts or flat plate carousels that are midthigh to waist level high are ideal (24-30 inches). This allows bags to be lifted in a good ergonomic position, minimizing back bending. Single pier belts can reduce capacity.

Double decker pier conveyors are great for increasing capacity in a limited space but are not recommended as they require employees to lift from the lower belt, often below knee height, and from the upper belt, often at shoulder height for smaller employees. This places more stress on the back, shoulders and arms. Back bending and overhead lifting are also difficult for older employees. Double pier conveyors also introduce the potential for employees to hit their head on the upper belt frame and structure when accessing bags from the lower belt.

Depth. Most conveyors are fairly wide to accommodate larger size bags. As a result, smaller bags can be too far from the edge and increase the reach. Conveyors that allow bags to be close to the edge without falling off minimize the horizontal reach distance to pull or lift the bag (<=30 inches maximum). Diverters and "bumps" can be used to push bags closer in loading zones and push bags back in when going around corners on carousels.

Bollard/conveyor protection. Steel tubular bollards are used to protect the conveyor from damage of being struck by powered tuggers and other equipment. The bollards' horizontal distance from the conveyor and vertical height determines ergonomic risk to employees. In a field study, Zavitz found that bollards that are too far from the conveyor (i.e., a 6-12-inch gap between the conveyor and bollard) result in more back bending and reaching and a 28% increase in spinal disc compression risk.

Here are three best practices related to conveyor protection.

1. No bollards or impact protection at employee conveyor loading zones is the preferred solution offering the lowest ergonomic risk. This allows employees to get as close as possible anywhere along the conveyor.
2. If bollards or conveyor impact protection are necessary or required, the bollard should be installed intermittently along the conveyor with dedicated loading zones or locations that allow employees free access to the conveyor via cutouts. If this is not possible, bollards should be as close as possible (1 inch) to the conveyor face/edge to minimize reaching and bending.
3. Curbs, another form of conveyor protection, are not recommended as they raise the height of the employee compared to the cart or container and require more bending when loading the cart/container. Curbs can also create a trip hazard.

Baggage loaders and lift assists

There are several different equipment options for baggage loaders and lift assists depending on the specific applications and design of the bag room and carts/containers. These include overhead lifts, side loading lifts and semi-automated manipulators.

Overhead lifts. These are common in manufacturing and have been used for years. Three common designs are hook, vacuum and fork. Hook design overhead hoists systems use a rail system mounted to the floor, ceiling or an existing pillar. Attached to the rail system is a powered hoist with a hook on one end to lift the bag and a pendant control handle that allows an employee to control the hoist. These systems were introduced for baggage handling in 1998 in Europe.

Advantages: Proven technology used for decades; easy to use, fast, smooth and reliable. Disadvantages: They can only be used on single pier conveyors and open baggage carts and baggage with handles used to lift; bags without handles or straps cannot be lifted with the hook and must be lifted manually; the hook can damage luggage; the use of one arm may create asymmetric postures and spine loading.

Vacuum systems are similar to overhead hoists; instead of a hook, they use a vacuum tube with a suction cup to lift. The overhead rail system and pendant controls are similar to the hook design.

Advantages: it's easy to use, smooth and reliable; a vacuum has an advantage over hook systems by allowing bags to be lifted from any flat surface with less potential damage. They also allow the user to rotate the bag for easier transport and a subsequent lift, if necessary. An *Applied Ergonomics Journal* study by Lu, et al., (2018), found vacuum lift systems can reduce spinal disc compression by 39% and shear forces by 25%.

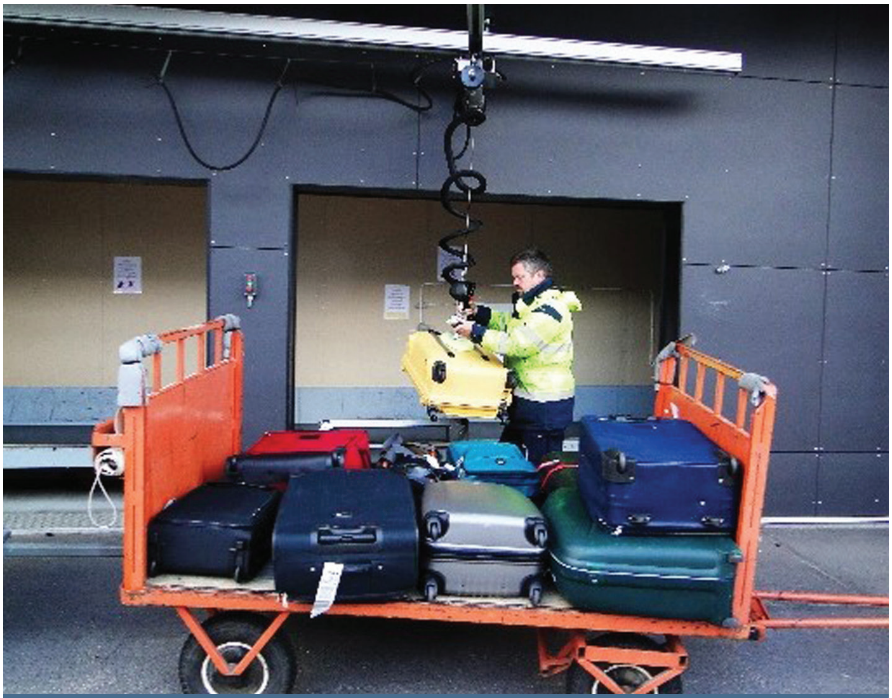
Disadvantages: They are slower than a hook system and can only be used on single pier conveyors and open baggage carts; they may lose suction and drop bags and cannot be used on all types of bags; the use of one arm may can create asymmetric postures and spine loading.

Fork design systems are similar to overhead hoists with a rail system, pendant controls and electric or pneumatic power. The difference is the end effector; instead of a hook or a vacuum, they use two forks or rails to lift heavy objects, similar to a forklift. These are most often used for oversized baggage.

Advantages: It's easy to use, smooth and reliable and allows for oversized and heavy objects to be lifted; it can be used with single and double pier conveyor designs and open and closed baggage carts and containers. Disadvantages: It is slower than vacuum and hoist systems and needs more floor space to operate than other overhead systems due to the long forks, making it more challenging to use in tight spaces.

Side loading lifts. Side loading lifts were specifically designed to address the disadvantages of the overhead lift systems, specifically their inability to be used with double pier conveyors or closed baggage carts and containers. There are three primary designs manufactured in Europe.

The original container loading system (CLS) was developed by LiftsAll Airport Handling Solutions in cooperation with baggage loaders at Stockholm-Arlanda Airport. The CLS uses an extending linear rail with a roller ball platform that allows the platform to be moved horizontally back and forth between the conveyor and the baggage cart or container. It is attached to an overhead rail system that can be ceiling- or floor-mounted. Using a simple handle paddle design, the CLS can be raised and lowered vertically to different heights and moved horizontally to different positions. The CLS essentially acts as an "extension of the user's arm" and replaces the lifting of bags with pushing and pulling motions. It is positioned beside the conveyor; the employee pulls the bag onto the CLS platform and the unit is moved to the baggage cart, where the employee pushes the bag off the platform into the cart.



An example of an overhead vacuum lift.

Photo courtesy of LiftsAll Airport Handling Solutions

Advantages: It can be powered by compressed air or electric; can handle loads up to 40 kilograms (88 pounds) at a rate of 10 bags per minute and is not sensitive to bags being dropped onto the unit; can be used with single and double pier lateral conveyor designs or moving carousel, and with open and closed baggage carts and containers; and can be custom designed to specific applications.

CLS is easy to learn to operate and uses normal pronated hand positions and grips (similar to baggage handling) to control the unit. It can be used with hard or soft bags. The extension platform allows bags to be placed precisely inside the container or cart to allow for the most-space efficient loading. The end of the CLS unit can also be used to push bags inside the cart without the need for the employee to reach or bend inside.

Zavitz conducted an applied research experiment (2020) and found that the CLS eliminates high peak spinal disc compression forces and reduced electromyography (EMG) muscle activity by 55% for the back and 37% for the shoulders compared to manual lifting.

Disadvantages: Bags still need to be manually handled with the CLS; it eliminates the high risks associated with lifting and replaces it with pushing and pulling motions and forces that are 20-40% of the bag weight; and is slower than manual loading.

STACK@EASE. This system is designed to function intuitively as an extension of the baggage handler's arm. The concept uses a disc-shaped bamboo platform at the end of a rotating, extendable, height-adjustable arm to move bags from conveyor to container. The handler brings the disc to the desired location and slides each bag on and off. The arm is responsive to both the weight of the bag and the operator's manipulation, and moves however the operator chooses by simply grabbing the disc. The arm is attached to an overhead rail.

Advantages: Electrically driven power can handle loads up to 88 pounds; it can be used with hard or soft bags on single and double pier lateral conveyor designs or moving carousel with open or closed baggage carts and containers; the arm and disc platform allows bags to be placed precisely inside the container or cart to allow for the most-space efficient loading; it's easy to use and operate by grabbing a disc underneath the platform and can be integrated with RFID technology to speed up the process.

Disadvantages: Bags still need to be manually handled; it replaces lifting motions with pushing and pulling motions; the disc design uses an underhand grip, similar to a bicep curl, which can be unfamiliar to some employees; two hands are used to move and control the unit; controls are on the disc, which requires employees to reach more inside the cart or container when loading at the back of the container; the unit is sensitive to heavy bags and can be overloaded if a heavy bag is dropped on the platform; the bamboo disc is small and larger bags can fall off or need to be held with one hand, reducing the control on the disc when moving the device; it is slower than manual loading.

Baggage loader. The baggage loader uses a platform with small roller balls that allow bags to be pulled onto the platform from the conveyor and pushed off into the baggage cart or container. The loader is attached to an overhead rail system mounted to the ceiling or floor. A simple handle with buttons allows the loader to be raised and lower vertically to different heights and moved horizontally to different positions.

Advantages: It is powered by compressed air or electric; can handle loads up to 110 pounds and is not sensitive to bags being dropped onto the unit; is easy to learn to operate and uses normal pronated hand positions and grips to control the unit; can be used with hard or soft bags and on single and double pier lateral conveyor designs or moving carousel with open or closed baggage carts and containers; the platform can be folded up when not being used to reduce floor space.

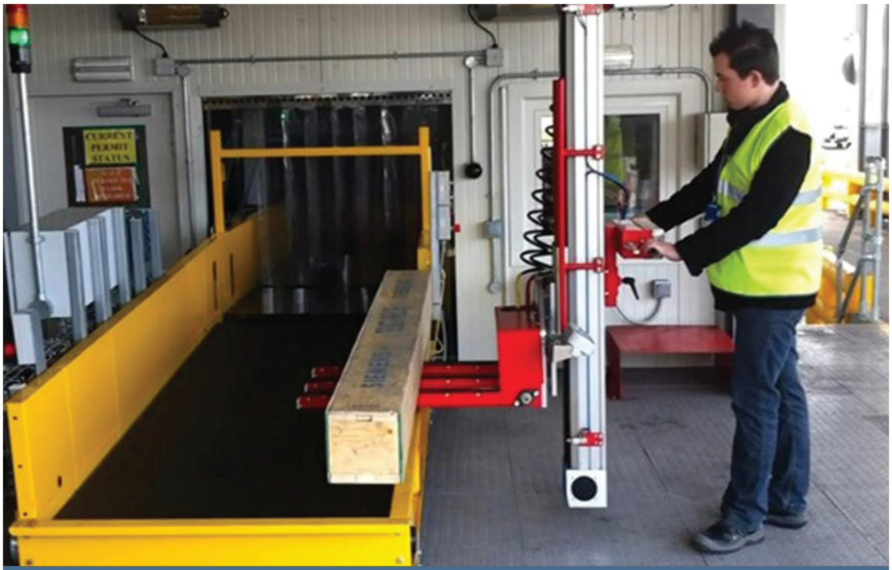


Photo courtesy of LiftsAll

An example of an overhead fork design lift.

Disadvantages: Bags still need to be manually handled; it replaces lifting motions with pushing and pulling motions; the platform does not extend like other similar devices, requiring employees to push harder to move the bags deeper into the container; it cannot be used for precision loading.

Semi-automated baggage manipulator. The baggage manipulator is a highly efficient semi-automated loading device for speed loading bags into baggage carts or containers with high efficiency and improved ergonomics. It allows a single operator to control an entire flow or batch of bags while loading into a cart or container. The baggage manipulator easily integrates into existing systems and can enable shorter loading windows to allow the baggage operators to handle a higher number of items. It uses a simple joystick control that allows bags to be loaded with precision without any manual effort.

Advantages: It allows for a high volume of bags to be loaded (960 per hour) by one operator with precision via a joystick; eliminates the ergonomic risk from manually handling bags, as there is no lifting, lowering, pushing, pulling or carrying of bags; can handle any bag weighing up to 110 pounds; reduces risk of damage to bags due to less manual handling.

Disadvantages: Cost, requiring long-term planning and capital, as an automatic baggage storage and retrieval system is needed to best utilize the manipulator; bags need to be loaded as a complete container or cart for a specific flight; multiple flights cannot be worked at the same time on the pier.

Integrated robot. The integration of robot technology is not just about replacing manual baggage makeup areas with automated machinery; it is also about adapting the overall process and environment for a higher level of automation. Modifications to existing baggage handling systems can help support the migration toward integrated robot loading. Robots automatically load bags into containers with no human handling.

Advantages: It eliminates the ergonomic risk of manual loading of baggage; lowers overall cost of labor, reduces errors improving process quality and improves bag security.

Disadvantages: Cost, requiring long-term planning and capital, as an automatic baggage storage and retrieval system is needed to best utilize the robot; bags need to be loaded as a complete container or cart for a specific flight; multiple flights cannot be worked at the same time on the pier; buy-in from operations, unions and employees could be challenging.

Conclusion: A solution matrix

Rates of MSD in baggage handling continue to be high despite advancements in ergonomic science and technology. One reason is that implementation of sustainable ergonomic solutions that prevent MSD have been slow to be adopted by airlines and baggage handling companies.

Marc G. Weinstein's solution matrix (*A Roadmap To Diffuse Ergonomic Innovations In The Construction Industry*, 2007) provides us some insight. The matrix uses four categories based on the complexity of the solution (simple or complex) and the time necessary to implement (short or long term). Adoption of solutions depends on the commitment of the organization to initiate interventions and of the workers to implement their use (Figure 3, Page 40).

The most commonly used ergonomic interventions for baggage handling primarily have been lifting training and administrative/work practice controls. These solutions would be considered category one or two, low cost and easy to do, according to the solution matrix. Unfortunately, these types of solutions have been shown to be less effective than long-term engineering controls. The criteria developed by Weinstein are important characteristics to assess adoption of a new solution, but when complex solutions are needed additional factors must be addressed to support adoption.

Long-term engineering solutions are considered complex solutions that require a shift in culture, are outside the norm of the current process, involve multiple stakeholders and require a concerted effort to monitor the integration of the solution into daily operations.

According to A.M. Dale, et al., in *American Journal of Industrial Medicine* (2018), for change to be effective, these criteria are needed: good understanding of risks; good metrics; an understanding of Weinstein's criteria for adoption; process measurement; stakeholder agreement; capital expenditures; and patience. Finally, the cost-benefit analysis of the suggested equipment is needed to facilitate the implementation of engineering solutions for baggage handling.

In a future article, we will discuss the eight barriers to adoption of long-term engineering equipment and technology in the baggage handling industry and share solutions for the ramp and aircraft. ❖

Authors' note: The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of NIOSH, Centers for Disease Control and Prevention (NIOSH/CDC). Mention of any company or product does not constitute endorsement by NIOSH/CDC.

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Ergonomics society adapts to reach goals

By Ben Zavitz and Gary Allread

The value of ergonomics is its ability to improve a wide-ranging assortment of jobs and activities, as well as the designs of products and equipment. This makes the use of ergonomics principles important to many professionals besides ergonomists, such as engineers, health and safety personnel and other technical specialists who work on company ergonomics-related challenges. This is one reason the Applied Ergonomics Society (AES) was created as a worldwide resource for those involved in ergo efforts to reduce injuries, improve workplace performance and quality, and develop an engaged, dedicated workforce.

Our mission at the AES is to provide information, expand knowledge and provide networking opportunities that enhance the skills and effectiveness of ergonomics practitioners and professionals. Our main goals have been to grow membership by extending value through meaningful interactions and information; prove growth of members through education, networking and collaborations; and create a consistent identity for the society that is recognized within the ergonomics industry. To reach these goals, we have recently:

Expanded the website and range of ergo solutions for members. This includes access to new research in the journal *IISE Transactions on Occupational Ergonomics and Human Factors*, news and trends in the field, ergonomics case studies and solutions, assessment tools, and ergo programs and guidelines.

Diversified newsletter topics. Examples of this include broadening the range of content on our monthly newsletters, featuring a blend of current topics/news and research, summarizing practical ergonomics applications and profiling society members and their experiences to appeal to a wider range of practitioners and users of ergonomic information.

Broadened involvement of colleagues. This includes reaching out to new groups of practitioners through the Applied Ergonomics Conference and its Ergo Cup teams, as well as to students. We offer special memberships to attendees of the AEC, Ergo Cup teams, students and those in academia. The AES has collaborated with other associations and groups, including the International Ergonomics Association, the Board of Certification in Professional Ergonomics and the NIOSH/