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Human Factors Engineering to reduce workload of baggage handling

Manual baggage handling cannot be avoided for aircraft container loading and unloading. Most bags will be heavier than ergonomic guidelines indicate as safe, thus posing health risks. The HF challenge is to find engineering solutions to reduce the manual workload on an individual level. A leading manufacturer took the challenge to engineer for reduced workloads. The engineering process, the human factors input, as well as some results are presented in this article.

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Once you have checked-in your far too heavy bag at the airport, it is processed in an automated sorting and storage system. For small regional aircraft baggage is transported to the ramp and stowed manually in the hold. For large long haul aircraft, your bag usually is manually loaded into aircraft containers (ULDs). Lifting aids are difficult to apply, because most types of ULDs are closed at the topside. There is no literature specifically on ULD loading. Oxley (2009) conducted a questionnaire on musculo skeletal symp toms for baggage handling at a regional airport in the UK. Of the handlers, 73% reported back pain, 51% kneepain, and 43% shoulderpain. Musculoskeletal disorders account for 50% of the personal injury incidents reported from UK Airports, the majority occurring during ground handling activities. Koelewijn (2006) reported workload reducing effects of a mechanical small aircraft loading aid, called the 'Rampsnake'.
Although airlines hardly publish data on the weight distribution of bags, it should be no surprise that musculoskeletal disorders are reported by the workforce. The maximum weight of a bag the airline usually allows for is 23 kg (economy class) or 32 kg (business class). Unfortunately, weight distribution data are not shared by airlines. One source indicated for long haul flights that 16% of the bags weights <15 kg, 18% between 15-19 kg, and 66% >19 kg; the overall average being 22 kg. Here, the maximum weight of economy class bags is 23 kg, and 32 kg for business class.

Guidance for optimizing baggage handling situations can be found in Duignan (2005). A project standard of British Airport Authorities BAA (Simmons, 2006) states: The design must reduce the risks to the lowest level reasonably practicable, ideally by automating or mechanizing the process. Where manual handling is unavoidable, ergonomically designed workplaces must be provided. However, the risk considered acceptable is not specified.

Figure 1. Loading a ULD with partially closed topside; to the left of the handler, bags arrive on a conveyor belt. This situation is called a build lateral, for 'building' a flight.

Airports accept the NIOSH technique for calculating a maximum acceptable weight of bags. However, few act on the outcomes. The NIOSH technique itself is an easy to understand set of rules to estimate the acceptable maximum lifting mass. Six workplace factors determine a reduction of the maximum lifting mass of 23 kg. For engineering purposes, for baggage handling four factors can be set at a fixed value (lifting height 50-100 cm; vertical displacement < 35 cm; good lifting technique; bags having a moderate grip). The remaining formula for the Recommended Weight Limit (RWL) = 19.3 x Horizontal factor x Frequency factor [Kg]. Hence, if you engineered a good working height, and the vertical displacement is limited, the remaining 'tools' for an engineer to reduce workload lies in the horizontal factor, i.e. to position the center of gravity of a bag as close as possible to the handler.
Other improvements require organizational measures, such as reducing the lifting frequency or lifting by two handlers. Of course this assumes a suitable working height, limited vertical displacement en trained handlers. Considering that only 34% of bags is less than 19 Kg, two third of the bags still weigh more than any calculated RWL.

How to tackle this problem? This article describes the case of the design of a new baggage handling system at a large UK airport.

Engineering process

Baggage handling includes loading and unloading of ULD's for large aircraft and on the ramp for small aircraft. A baggage handling system also includes several other tasks, such as manual coding for labels on bags that could not be identified by scanners, or bags without a label (or unreadable label). Both tasks require to manipulate heavy bags at a coding workstation. Based on the general description in the introduction, the work system for a HF based approach should not be limited to ULD loading. It should include all baggage handling tasks, in order to be able to apply work organizational measures in an integrated systems design, such as task rotation.

Starting point of the project is the contract awarded to the baggage system manufacturer. A detailed ergonomic design of workstations was required. The HF input has been organized as follows:

1. Orientation on project setting. HF requirements were specified by a UK ergonomics consultant on behalf of the contractor. The specifications established guidelines and legislation, however no feasible solutions. Therefore, the manufacturer hired HF Professionals to assist in detailed design and engineering.
2. For the HF professionals, the project started by organizing an ergonomics workshop for system engineers. The goal of the workshop was to provide a good understanding of the ergonomics aspects of manual handling. Amongst others, it included an introduction in the NIOSH-technique.
3. Analysis. The situation analysis consists of gathering data on luggage, planning and tasks at the existing airport, as well as for the new terminal (functional task analysis). Due to Union regulations, the manufacturer (and thus his ergonomist) was not allowed to do his own task analysis. They had to rely on the reports by the aforementioned UK consultant.
4. A series of three brainstorm sessions on how to improve state-of-the-art systems. The sessions were organized in a format of a walk-through-talk-through of the full baggage sorting system with engineering and HF-staff. During the sessions HF issues and principles were discussed. Systems engineers developed, whenever possible, alternative design solutions.
5. Impact study to estimate the effects of design solutions on postures and workload.
6. Mock-up studies. Detailed design of workplaces (ULD loading, manual coding, problem bag) were tested on the building site and at the local office of the manufacturer.
7. Pilot observational studies of several semi-automated bags handling systems, in particular an Extended Belt Loader (EBL, see Engineering).
8. The HF Professional reviewed the detailed design of all workstations and compiled a review report for each workstation, to be approved by the contractor.

Engineering

The airport terminal is expected to handle 50.000 departing bags per day. For this, 36 manual handling stations, each manned by two handlers, will be needed. Bags arrive on a conveyor belt. Handling includes: (1) scan label, (2) determine ULD, and (3) transfer bag from conveyor to ULD. Four or more ULDs will be located parallel to the conveyor. Scanning and loading may be segregated over two handlers at the conveyor. One handler would do 1-3 bags/minute.

The first brainstorm session considered improvement of the manual work at the conveyor. Assuming continuous lifting during > 2 hours/day, the best possible NIOSH Frequency factor would be 0.80, reducing the RWL from 19.3 to 15.0 kg. Therefore, it was decided to categorize bags >15 kg as heavy, to be handled either mechanically or by two persons. For < 15 kg bags, an improved workstation design might be sufficient. Methods to reduce the horizontal reach by narrowing the belt and/or mechanical rotation of the bag, were considered (figure 2), as well as bringing the bag closer to the ULD without lifting (for example using flexible roll tables). However, lifting is still required and risks will not be reduced significantly. Lifting aids can be applied, provided fast and easy positioning above the lifting area as well as above the destination area. For closed top containers suitable lifting aids (figure 2) were not on the market at the time of the project.

The second brainstorm session concentrated on mechanization. The contractor had ordered two robots and three semi-automated loading devices. The robots operate at a speed of 4 bags/minute plus idle time during ULD change; output is estimated at 6 ULDs per hour (there are 12 ULDs in a long haul flight). The robot manufacturer suggested one operator to supervise 2 robot stations. In practice, failure rate goes up for the last 10% bags. Hence, manual topping-up would be required. Two robots reduce the total amount of

Figure 2. Sketches for brainstorm session (left: reduce reach; right: lifting aid).

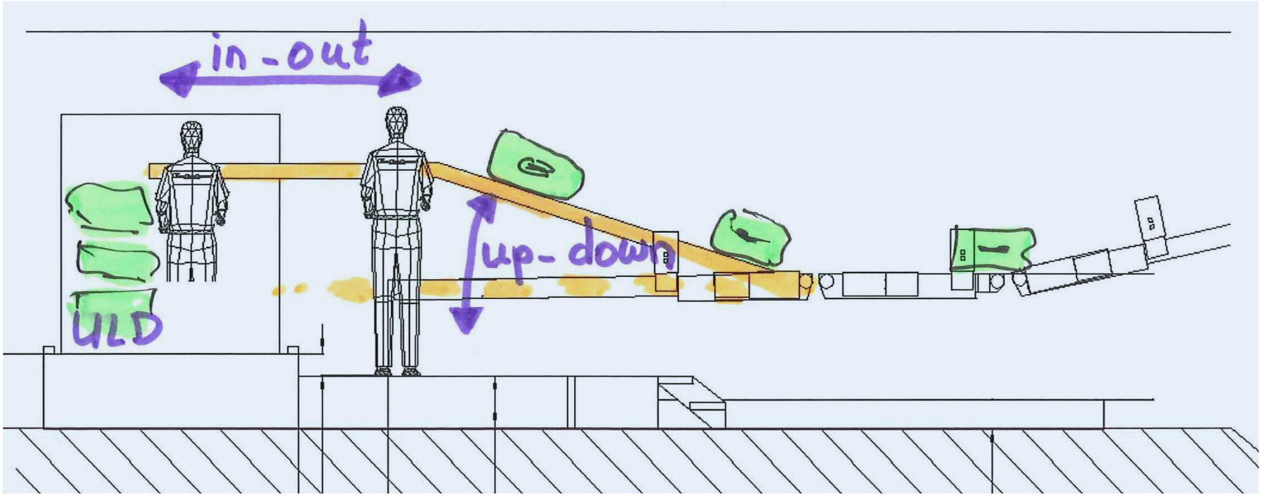

Figure 5. Typical of an existing problem bag workstation.

manual lifting by 12% (6.000 of 50.000 bags). If the number of build laterals (and handlers) is reduced accordingly, there will be no effect on the workload of the remaining handlers.

Semi-automated loading by an Extended Belt Loader (EBL) was considered next. According to Riley (2009) and Koelewijn (2006), EBL reduces the risks of injury significantly. Characteristic feature is a horizontal and vertical adjustability, requiring little lifting, nor body rotation or bending. Bags are moved mechanically onto the right position in the ULD. The handler gives a one handed push. Handling frequency is 4-6 bags/minute (twice the loading frequency without EBL). A pilot observational study was performed regarding operator work postures. The manual workload and related postural risks are reduced significantly, compared to a build lateral. All handlers will be able to control an EBL, therefore, task rotation is feasible.
At the brainstorm session, the question was raised whether an EBL could be combined with conventional build laterals (conveyor). Several options were discussed, inevitably leading to additional space requirements, which was hardly available in the proposed baggage hall. At a build lateral, the largest reduction of manual handling can be obtained, when the EBL is used for fast runners (those are the bags for ULD's marked for economy class passengers). Overall manpower reduction would be significant for EBL's.

On an individual level, manual handling risks can only be reduced if one considers job content and local work organization. The impact of the Frequency factor (NIOSH) is significant. If the manual lifting period is <2 hours, this factor is 0.84, compared to 0.65 for 2-8 hours lifting (at 2 bags/minute). The lifting frequency is influenced by the number of handlers, bags and available time. A longer build time and the same number of bags and handlers, results in a lower frequency per handler and thus reduced risks. If periods of continuous lifting can be alternated with other tasks, this also reduces manual handling risks. Whether lifting can be reduced to a few hours per day, depends on how the tasks are organized (Schreibers, 2006). EBL-technology, combined

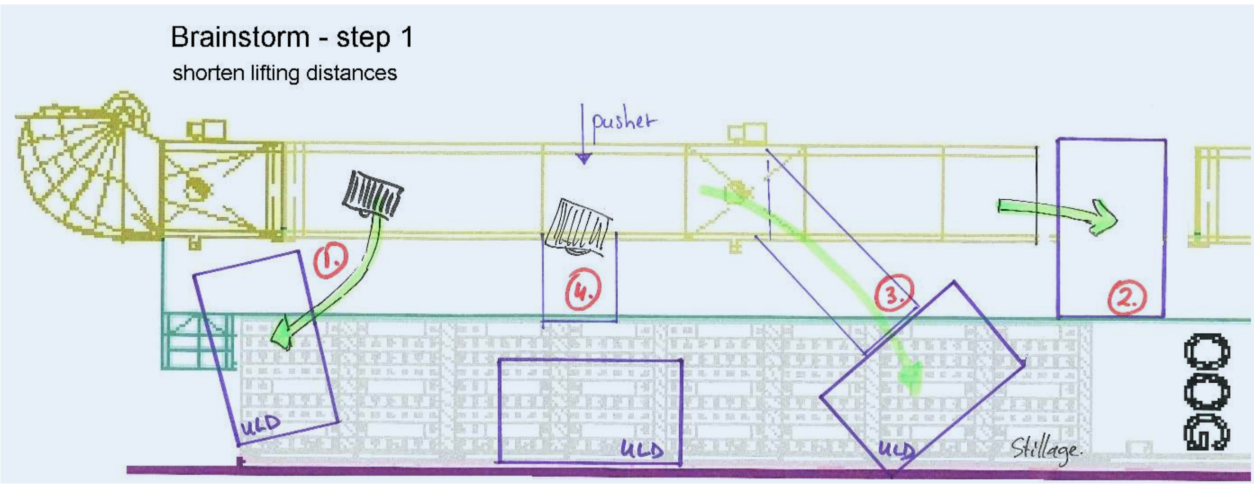

Figure 4. Sketch of measures to shorten lifting distances at a build lateral. For positions marked 2 and 3, an EBL could be emphasized.

Figure 5. Typical of an existing problem bag workstation.

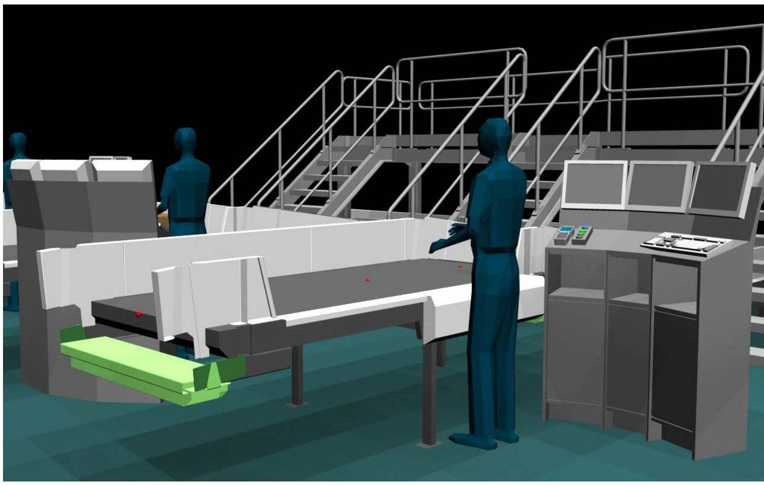

Figure 6. Redesign of a problem bag workstation (also realized as a mock-up).

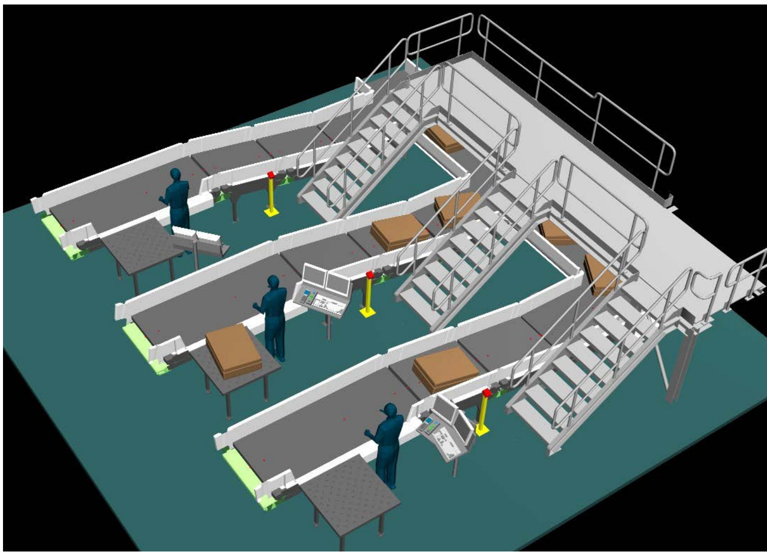

Figure 7. 3D-design of several alternative problem bag workplaces.

with a conventional lateral, has a significant effect. Handlers may rotate over 3 tasks: scan, manual loading, and semi-automatic loading (handling without lifting). These non-engineering solutions were introduced to the contractor, however discarded. Several factors played a role:

1. organizational changes were said to be very expensive, probably because it requires negotiations with labor unions;
2. compared to robots, the EBL technology was not looking fancy to project airport management;
3. non-engineering recommendations by the manufacturer were rather uncommon and were not asked for (contracted).

Detailed design of workplaces

For each type of workplace, a (standardized) detailed design document was needed, including measurements, specification of controls and displays, layout, et cetera. For example, for the build laterals (conveyor to ULD workplaces), field tests were done on readability, screens size, and location of displays at the conveyor. For problem bag and manual coding workplaces, mock-ups at the building site (next to the conveyor systems already installed) were organized.[1] The mock-up sessions proved to be fruitful exercises, because it visualised alternative design solutions. This enabled representatives of the end users and operational management to get an idea of the new workplaces and to compare them with other workplaces at the airport.

The figures 5, 6 and 7 show an existing problem bag workstation, and the design of the new problem bag handling area. It shows three different layouts for positioning the workstation with computers screens and controls, the conveyor belt, and the table for bag inspection. Probably the major result of the mock-up session has been to show that there are indeed alternative solutions.

Organizing a mock-up session on a building site has not been very easy, due to safety and security requirement, the fact that was a rather unusual activity (at least at this airport), and lots of restrictions caused by union regulations. For example, the ergonomist was not allowed to use tools (such as a screwdriver) on the building site. Assembling the mock-up had to be done by one or two carpenters. In the end it was decided to relocate the mock-up sessions to the local office of the manufacturer.

1 Photographing at the mock-up sessions was not allowed. For pictures of bag handling worksituations, we refer to: VanderLande (2018); www.vanderlande.com/airports/innovative-systems/make-up/stack-ease.

Discussion

This case study discusses a baggage handling system design. There has been no intention to discuss the scientific background of manual handling and postural risks. For engineering purposes, estimates are sufficient to understand the effects of engineering solutions. Based on this understanding, engineers developed new solutions for HF challenges. First ideas usually concern workplace design, however ineffective for this case. Next, full automation (robot) is considered, still requiring supervision and manual topping-up. Nowadays, advances in robot control largely solve the latter. And although the number of manual handlers decreases, the individual workload will not be reduced.

Semi-automation (EBL), keeping the handler in the system and redesigning the work organization was shown to have more potential in reducing individual health risks. After completion of the project, the development of engineering solutions continued. The EBL has been developed into new loading devices (VanderLande, 2018).

At the manufacturer an appreciated and effective first step has been the briefing of systems engineers on the backgrounds of human factors guidelines, as well as the brainstorm sessions. Looking back at the project, the main obstruction for realizing innovation has been that idea generation by the contracted manufacturer comes too late. These considerations, including cost-benefit analyses, negotiations with unions, et cetera need to be done up-front a project, preferably by the project owner.

The considerations given here apply to other logistic systems, as exemplified by a report on parcel sorting at Australian Post (Hehir & Pikaar, 2015). Here, task rotation became an important part of system design and implementation. At Australian Post, the EBL technology was successfully introduced for truck and container loading with loose parcels.
In conclusion: HF Professionals are needed up-front projects. Case studies are needed to show the value HF Engineering.

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Samenvatting

Het handmatig beladen van vliegtuigcontainers is niet te vermijden. De meeste koffers zijn zo zwaar dat er sprake is van gezondheidsrisico's. De uitdaging is om HF-engineering-oplossingen te vinden, waarmee de belasting van het handmatig tillen verminderd kan worden. Robots zijn kostbaar en vervangen de arbeid, maar verlagen de werkbelasting voor de overige individuele medewerkers niet. Een leidende fabrikant van bagagesystemen nam de uitdaging aan om tot echte innovaties te komen. Het ontwerpproces, de HF-inbreng en de resultaten van een praktijkproject worden in dit artikel besproken.
Dit artikel is gedeeltelijk een bewerking van Pikaar en Asselbergs (2011).

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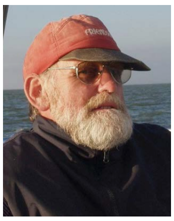

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