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Systems Engineering – Innovation in airport baggage handling

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Abstract. Manual baggage handling at aircraft container loading cannot be avoided. Over 80% of the baggage will be heavier than ergonomic guidelines indicate as safe, thus posing occupational health risks. The HF challenge is to find engineering solutions to reduce the manual workload on an individual level. Automation is relatively costly and may not be effective, if the number of baggage handlers is reduced also. Hence, more innovative approaches are needed. A leading baggage handling systems manufacturer took the challenge to engineer for reduced workloads. The engineering process, the human factors input, as well as an overview of the results is presented in this paper.

Keywords. Systems Ergonomics, HF Engineering, Manual Handling, Work Organization.

1. Introduction

Once you have checked-in your far too heavy bag at the airport, it is processed in a sorting system. At the end of the system your bag is manually loaded into aircraft containers (so called ULDs). Lifting aids are difficult to apply, because most types of aircraft containers have a closed topside. At long haul flights, roughly 16% of the bags weights <15 kg, 18% between 15-19 kg, and 66% >19 kg; the overall average being 22 kg. Over 80% exceeds a weight that guidelines indicate as safe. Literature on baggage handling focuses on tasks on the ramp, i.e. aircraft loading. For example Oxley (2009) conducted a questionnaire on musculoskeletal symptoms for baggage handling. Of the handlers, 73% reported trouble with their lower back, 51% in their knees, and 43% in their shoulders. Musculoskeletal disorders account for 50% of personal injury incidents reported from UK Airports, the majority occurring during ground handling activities. Koelewijn (2006) reported on the workload reducing effects of a mechanical aircraft loading aid. In a literature overview report, Riley (2009) suggests a bag weight limit of 23 kg. This would reduce handling risks, though it would be difficult to quantify the likely amount of risk reduction.

For the Human Factors (HF) Engineer, the challenge is to find solutions that reduce the bag handlers workload. Introducing automation doesn't change the individual workload, if the number of baggage handlers is reduced by the same percentage as automation increases. A leading baggage systems manufacturer took the challenge to develop new solutions for this problem. A systems ergonomics approach was introduced to assist the systems engineers (section 3).

This paper is based on case material. Case studies have a methodological problem. The same project is never done twice (a balanced experimental design, for example with and without ergonomics). Nevertheless, case studies contribute to the development of ergonomics as a science (Pikaar, 2008). For this project a systems ergonomics approach has been applied (Pikaar, 2007). As an add-on, the case included the possibility to compare a recent baggage system and the new design.

2. Baggage handling at the airport baggage hall

In the USA, the OSHA-website (osha.gov/SLTC) is one of the few, giving guidance for baggage handling in the baggage make-up room. The guidelines aim for optimizing lifting situations. Other comparable guides can be found (for example Duignan, 2005). Simmons (2006) states in a project standard of British Airport Authorities (BAA): *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*. The problem is, that the level of risk considered acceptable, is not specified. In general, airports seem to accept the revised NIOSH method (Waters et.al, 1993) for calculating a maximum acceptable weight of bags, however they don't act on the outcomes (most bags is too heavy).

NIOSH defines "acceptable" as an arbitrary risk of 1% that a healthy male adult may get complaints caused by the lifting task. The method itself is an easy to understand set of rules to calculate the acceptable maximum lifting mass. Six workplace factors determine lifting limits. For ideal circumstances each factor is 1.0. For less ideal circumstances factors are < 1.0. Thus, each factor contributes to a reduction of the maximum lifting mass of 23 kg, set by scientific research for ideal circumstances. For engineering purposes in a baggage hall environment, the following factors can be set at a fixed value:

Vf = 0.93 (lifting height always between 50 and 100 cm)
Df = 0.95 (vertical displacement maximum 35 cm)
Af = 1.00 (good lifting technique; no body rotation needed)
Cf = 0.95 (bags have at least a moderate grip).

The remaining formula for the Recommended Weight Limit (RWL)=19.3 x Horizontal factor x Frequency factor [Kg]. In practice, over two-third of the baggage will weight more than the RWL. Therefore, a statement by airlines would be welcomed on what they consider to be an acceptable risk level for baggage handling personnel.

The authors are aware that, over the years, Ergonomics/HF research has provided much more data and guidelines on working postures and manual handling. Also there is a debate on the validity of the NIOSH equation and its starting points. These scientific backgrounds will not be discussed in this paper. Considering the aim of the ergonomist to assist the systems engineers at the development of a new production system, relatively rough estimates will do in order to understand the effects of specific engineering solutions, i.e. whether a specific solution would effectively help reducing risks.

3. Engineering process

This case concerns the renewal of a baggage handling system at an international airport. Four years earlier the baggage systems manufacturer had delivered a new baggage hall at a new terminal of this airport. At that time an ergonomist had contributed to the detailed design of the workstations. Therefore, significant improvements of the workstation design should not be required. Another approach was needed, starting with a good understanding of all factors determining workload. The HF input has been organized as follows:

1. Workshop: understanding the ergonomics of manual handling.
2. Situation analysis: gathering data on luggage, planning and tasks of the earlier system (situation analysis), as well as on the new terminal (functional task analysis).
3. Series of brainstorm sessions *how to improve state-of-the-art systems* in a format of a walk through - talk through of the full baggage sorting system with engineering and HFE-staff. During the sessions HF issues and principles were discussed. Systems engineers developed, whenever possible, alternative design solutions.
4. Impact study to estimate the effects of design solutions on postures and workload.
5. Pilot observational studies of several semi-automated bags handling systems.
6. Finally the HF Engineer reviewed the engineering of all workstations and compiled a review report for the airport authorities (on behalf of the systems manufacturer).

4. Case

The airport terminal handles daily 90 long haul and 70 short haul flights between 5.00 and 22.00 hours, including 50.000 departing bags. A feasibility study indicated the need for 36 manual handling stations (so called build laterals) each manned by 2 handlers and room for 4 ULDs on a row. Given a build time (time to fill all ULDs of one flight), the estimated handling frequency per handler would be between 1–3 bags/minute. Handling of a bag consists of: 1. scan label, 2. based on scan, determine ULD, and 3. transfer bag from lateral to ULD. In addition ULDs have to be transferred to and from trolleys.

Work stations of the earlier realized baggage system were according to a correctly implemented HF design. A goal of the new project is to deliver a baggage hall with reduced occupational safety and health risks. In order to verify this goal, one needs to have knowledge of the work processes in the existing terminal. Here, there are 40.000 departing bags/day, handled at 132 build laterals, employing 200 handlers over 16-18 operational hours/day. Unfortunately, systematic observations were not allowed due to Workers Union regulations. We could only look around a bit. An interesting observation has been that the tasks of scanning and loading may be divided over both handlers at one lateral.

The first brainstorm session considered the manual work at build laterals. First, bags were categorized in terms of the NIOSH equation. Assuming continuous lifting (> 2 hours per day), the best possible Frequency factor would be 0.80. This reduces the RWL from 19.3 to 15 kg. It was decide to indicate bags >15 kg as heavy, to handled either mechanically or by two handlers together. Lifting luggage <5.0 kg usually is without risks. For 5-15 kg luggage, improved workstation design might help, in particular to optimize the

Horizontal factor, i.e. reduce horizontal reach. Methods to narrow the belt were considered (figure 1), as well as measure to bring the luggage closer to the ULD without lifting (flexible roll table). However, lifting is still required and actual lifting risks will not be reduced. Lifting aids can be applied, provided fast and easy positioning above the lifting area as well as above the destination area (otherwise it will not be used in practice). For closed top containers lifting aids are not very suitable or difficult to handle (see figure 1).

Figure 1. Sketches for brainstorm session (left: reduce reach; right: lifting aid).

The second brainstorm session concentrated on mechanization. The airport had ordered two robots and three semi-automated loading devices, including a transportation system for ULDs. Robots operate at a speed of 4 bags/minute plus idle times during ULD change; output is estimated at 6 ULDs per hour (there are 12 ULDs at 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. Therefore, the current approach is to load 80% (30 bags) by robot and do manual topping-up at a separate work station (6 bags). Robots reduce the total amount of manual lifting. If all handlers can rotate over 36 build laterals and 2 robot stations, the overall physical workload per handler may decrease by 12% (2 robots can do 6.000 out of 50.000 bags). In case the robot stations are manned by specialists (operators), there will be no effect on physical workload of individual handlers.

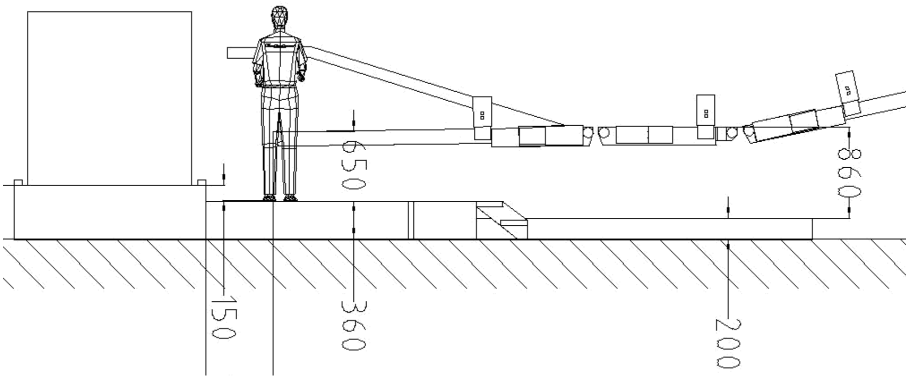


Figure 2. Sketch of extended belt loader (EBL).

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, body rotation or bending. Bags are moved mechanically onto the right position in the ULD. The handler gives a one handed push to most bags. Handling frequency is 4-6 bags/minute. Each EBL requires one handler. A pilot observational study was performed into operator work postures. The manual workload and related postural risks are reduced significantly, compared to a build lateral. Contrary to robots, it is safe to assume that all handlers will be able to control an EBL. Hence, task rotation can be organized.

The question was raised, whether an EBL could be combined with conventional build laterals, instead of located at a separate robot/EBL area. Several options were discussed, inevitably leading to the need for additional space. At a build lateral, largest reduction of manual handling can be obtained, when the EBL is used for fast runners (economy class) and/or can be easily switched between 2 ULD-positions.

It was concluded that manual handling can be effectively reduced by automated and semi-automated loading. However, robots are costly and need manual topping-up. EBL technology requires more space then conventional build laterals, which in this project is limited, though not impossible.

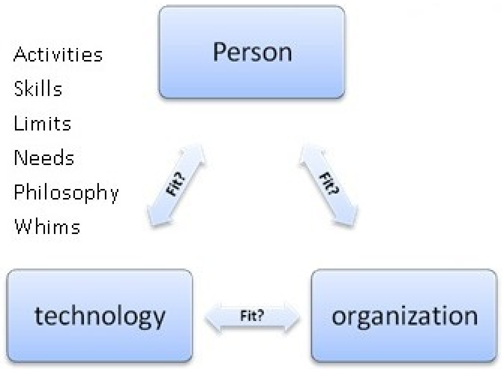
The brainstorm sessions also led to a list of non-engineering measures. On an individual level, manual handling risks can be reduced if one considers job content and work organization. At 2 bags/minute per handler, the impact of the frequency factor Ff (NIOSH) is high. For example: for moderate lifting periods (1-2 hours) the Ff is 0.84, compared to 0.65 for 2-8 hours lifting at 2 bags/minute. The average 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 a reduced risk level. If periods of continuous lifting can be alternated with other tasks, this also reduces manual handling risks. There is a lot to gain if lifting can be reduced to a few hours per day. Whether this is possible depends on how the tasks are organized (Schreibers, 2006). Here EBL-technology has a significant effect, because at a lateral one can rotate over 3 tasks: scan, manual loading, and semi-automatic loading (handling but no lifting).

The non-engineering solutions were introduced at the airport (project) management. However they were discarded quickly because of said high costs.

5. Discussion

First ideas to reduce manual handling risks are traditionally directed towards fitting the workplace to the man. In this case, further workplace improvement was not effective. Next, engineers and management go for automation (a fancy robot system), which is expensive and not a practical solution for the problem at hand (reducing manual workload risks). Semi-automation, keeping the handler in the system, and redesigning the work organization was shown to be more effective. Airport management could not be convinced of this approach, presumably because organizational change processes are considered difficult.

What we are looking at is a three way fit between men, technology and organization, as described in the Dynamic Dilemma Model (figure 3) by Gilmore and Millard (1998). To realize a 3 way fit on six aspects (tasks, skills, limitations, needs, philosophy and whims), it is recommended to adopt an integral systems approach (macro-ergonomics). In other words, jobs and work organization have to be "engineered" as well as the technical systems, preferably within an integrated approach. This should include consultancy on a management level.



At the manufacturer a first and most welcomed step has been briefing systems engineers on the backgrounds of ergonomics guidelines, including work organization issues. Secondly, innovation is needed in design solutions based on extended belt concepts. Thirdly, innovation is needed in organizing the baggage handler jobs.

Figure 3. Dynamic Dilemma Model – 3 way fit.

6. References

Duignan, C.A. (2005). Best manual handling practices at Dublin Airport. Dublin: HSA.

Gilmore, D.J., D Millard (1998). Integrating micro- and macro-ergonomics. HFES Annual Meeting Proceedings, Macro-ergonomics, pp. 964-968.

Koelewijn, B.R. (2006). RampSnake: a new working aid for loading an aircraft. In: Pikaar, R.N. (2006), Meeting Diversity in Ergonomics, Proceedings of the IEA2006 World Congress. Amsterdam: Elsevier.

Oxley, L., D. Riley, S. Tapley (2009). Musculoskeletal ill-health risks for airport baggage handlers – Report on stakeholders project at East Midlands Airport. HSE Books.

Pikaar R.N. (2007). New challenges: Ergonomics in Engineering Projects. In R.N. Pikaar, A.E.P. Koningsveld, & P.J.M. Settels (eds.), Meeting Diversity in Ergonomics (Chapter 3, pp 29 – 64). Amsterdam: Elsevier.

Pikaar, R.N. (2008). Ergonomics in Engineering Projects – How to achieve a booming business. In L.I. Sznelwar, F.L. Mascia and U.B. Montedo (Eds.), Human Factors in Organizational Design and Management – IX (pp. 495-500). Santa Monica: IEA Press.

Riley, D. (2009). Reducing the risks associated with the manual handling of air passenger baggage for narrow bodied aircraft – Literature review update. HSE Books.

Schreibers, K.B.J., J.P. de Groot, W. van Tuil (2006). How to design rotating tasks within jobs? In: Pikaar, R.N. (2006), Meeting Diversity in Ergonomics, Proceedings of the IEA2006 World Congress. Amsterdam: Elsevier.

Simmons, P. (2006). Baggage Handling Safety & Mechanical Hardware. Brithish Airport Authorities.

Waters T.R., Putz-Anderson V, Garg A., Fine L.J. (1993). Revised NIOSH equation for the design and evaluation of manual lifting tasks. Ergonomics, 36 (7), 749-776.