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Reducing the risks associated with the manual handling of air passenger baggage for narrow bodied aircraft

Literature review update

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RR674
Research Report

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Reducing the risks associated with the manual handling of air passenger baggage for narrow bodied aircraft

Literature review update

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This report is an update of the review for ramp-based baggage handling related literature undertaken in 2005 (Tapley and Riley, 2005). The aim of this review is to present information relating to alternative methods of loading narrow-bodied aircraft that reduce the manual handling related injury and ill-health risks to the handlers, and to identify knowledge gaps. This was used to inform subsequent work at East Midlands Airport in 2007/2008 (Musculoskeletal ill-health risks for Airport Baggage Handlers: Report on a stakeholder project at East Midlands Airport - RR675).

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CONTENTS

EXECUTIVE SUMMARY

Objectives

This report is an update of the review for ramp-based baggage handling related literature undertaken in 2005 (Tapley and Riley, 2005). The aim of this review is to present information relating to alternative methods of loading narrow-bodied aircraft that reduce the manual handling related injury and ill-health risks to the handlers, and to identify knowledge gaps. This is to inform subsequent work at East Midlands Airport in 2007/2008 (Musculoskeletal ill-health risks for Airport Baggage Handlers: Report on a stakeholder project at East Midlands Airport - ERG/08/15).

Main Findings

We have good information concerning the range of risks to musculoskeletal health presented by ramp-based manual baggage handling operations for Boeing 737 series and Airbus A 319 aircraft. We do not have observational evidence of the range of other aircraft types that typically require bulk loading of hold baggage and the methods used.

Introducing an international single item baggage weight limit of between 23 kg to 25 kg is a step that would have a positive effect in reducing the risk of handling related injury or ill-health to baggage handling workers, by eliminating the bags above this weight level that present the greatest risk. However, it appears that such a measure may not have a large effect on the average weight of items handled. It is difficult to quantify the likely amount of risk reduction. It will not mean that the injury and ill-health risks associated with manual loading and unloading of baggage is automatically at an acceptable level. At present there is relatively little information available concerning the nature of the baggage item weight frequency distribution. We understand that the frequency distribution for item weight is likely to vary according to the carrier, airport, route, time of year, etc., but without this information it is difficult for anyone to make truly representative risk assessments for baggage handling operations.

There is a range of existing and emerging devices providing mechanical assistance (and manual handling risk reduction), to the baggage handling process. These include both Ground Support Equipment, and in-hold systems, and combinations of both. There is good evidence for the benefit of mechanical assistance devices in terms of reducing physical workload, manual handling and MSD risks associated with baggage handling work on the ramp, and these are described in relation to each equipment type.

We need to analyse suitable footage of the Mallaghan LBT90 in operation in order to be able to make a comparison of the postures adopted with those for standard belt loader use. A suggested approach is to use OWAS to enable comparison with reported studies.

Benefits of an alternative baggage stacking method are reported. This appears to offer significant advantages in terms of reducing spinal loading. It is envisaged that the approach may be applicable in a limited set of circumstances, and for a proportion of any baggage load, but nonetheless the benefits are there, and if the approach can be adopted to any extent during loading activities, this will be beneficial. An alternative baggage stacking method appears to be a practicable means of reducing the risks.

Recommendations

Further work is required to gather data on the range of aircraft typically encountered in order to better understand the practicalities and realities of using belt loaders and other risk reduction measures.

The applicability of emerging technology to assist with baggage handling, particularly in the GB low-cost sector needs to be investigated.

Access to baggage item weight data is required, and industry cooperation will be needed in order to gather this.

A postural analysis of Mallaghan LBT90 use needs to be undertaken (and this was undertaken at East Midlands Airport).

Investigate the practicalities of using an alternative baggage item stacking method in operational conditions, and the extent to which it can be adopted.

1 INTRODUCTION

1.1 AIMS

This report presents the findings of an update to the review for ramp-based baggage handling related literature undertaken in 2005 (Tapley and Riley, 2005). A particular aim of this review was to identify information relating to alternative methods of loading *narrow-bodied* aircraft that are intended to reduce the risks of the handlers suffering from musculoskeletal disorders, and to identify knowledge gaps. This information has relevance to the handlers providing services to the budget airlines serving British (GB) regional airports.

The definition of narrow-bodied here is taken as that presented by Dell (2007):

> *"Single aisle passenger transport aircraft such as the Boeing B717, B727, B737, McDonnell Douglas DC9, MD83 and MD87 and Fokker F28 & F100, as well as all commuter aircraft, seating up to around 150 passengers, that are designed to have the baggage loaded in bulk, one item of baggage at a time".*

Although some of the aircraft types included in Dell's definition are not typical in GB, especially in the low-cost sector where most bulk (or loose) loading of aircraft is still performed, the Boeing 737 series and Fokker F series aircraft certainly are. We need to include the Airbus 320 family of aircraft (A318, A319, A320 and A321) within our definition as well as some others that meet the single aisle criteria. An alternative description of this group of aircraft would be 'regional airliners'. We also include the Boeing 757 family of aircraft as these are common in the low-cost sector and are routinely bulk loaded with passenger baggage at regional airports. A 757-200 can seat over 220 passengers.

This report was originally drafted in May 2007, however, it was agreed to keep it as a 'working draft' in order to capture further information and developments to inform a concurrent project in association with stakeholders at East Midlands Airport, and ending in 2008. This report therefore has a 2007 reference number, but was not issued until 2008.

1.2 BACKGROUND

Relatively little new information was identified through searching the Ergonomics Abstracts online database. The search terms used were: 'manual handling' combined with 'baggage' 'aircraft' and 'aviation'. This returned 23 articles, and these abstracts were reviewed to select ten for full text review. Other 'grey' literature has been included, much provided through personal communication, both with colleagues working in this sector within HSE and with external contacts. The principal source identified in this study is the review presented by Dell (2007) in his Doctoral Thesis (obtained by personal communication, Ballarat University). Dell's work represents the definitive review of baggage handling operations to date, and covers the work conducted in this area since the 1970's.

There is still relatively little in the way of published material, although there is now more than there was available even as late as the 1990's. Dell reports there being nine research papers specifically concerning manual baggage handling operations (generally) during his initial work towards his PhD in 1994. By 2005, Duignan (2005) reports there being less than 30 English language papers on the subject. Of the nine papers referred to by Dell (2007), several were evaluations of mechanical assistance devices:

- Jorgensen (1987) - the benefits of an 'ACE' loading system
- Stokholm (1988) – the benefits of the Sliding Carpet Loading System
- Egeskov (1992) – the benefits of using a belt loader to load Boeing 737 series aircraft.

Two further papers reported the results of investigations of different working methods for in-hold handlers:

- Stalhammar et al (1986) and Leskinen et al (1991) both studied the back injury prevention benefits of handlers resting supine during in-hold working.

Dell's (2007) thesis addresses the following questions:

- What is the scale and importance of the problem worldwide?
- What are the aircraft manufacturers doing about the manual baggage handing problem?
- What involvement have airline H&S staff had in reducing the injury risks?
- What are opinions of the handlers themselves?
- What are the benefits of the 'Sliding Carpet' and 'ACE' systems in reducing the risks?
- Are there any other 'solutions' in the form of ground handling equipment, and what are their benefits?

Dell reviews the manual handling activities of the ramp-based worker but also presents evidence that each item of passenger baggage is typically manually handled up to 10 times for each journey (up to 5 times at each end). Indeed, operations are very similar at almost all regional and larger airports worldwide. In a section on the history of airline baggage handling, Dell presents images of the operation from 1926, 1940, 1955, and 2000. The nature of the manual operation has not changed significantly, although the amount of air travel, and hence the extent and frequency of the baggage handling operation has increased.

Dell usefully also reviews the practice of manually loading wide-bodied aircraft bulk holds and containers, and the other manual tasks of a ground handler:

- Pushing/pulling loaded baggage carts
- Pushing /pulling of belt loaders
- Pushing/pulling aircraft steps
- Pushing/pulling containerized baggage inside the aircraft
- Pushing/pulling pallets of cargo on/of pallet trailers

He highlights that some airlines do not allow equipment to be driven up close to the aircraft by ground crew, due to the risk of collision and resulting damage. This means that for some handlers, the manual movement of belt loaders, baggage carts and aircraft steps is an 'every flight' requirement. The forces applied by workers in these situations are not quantified in Dell's thesis, and therefore the relative level of risk associated with these activities cannot be judged accurately. Ferreira and Riley (2007) conducted basic force measurements for the movement of typical aircraft steps (and baggage trailers) used with Boeing 737 series aircraft at Manchester Airport. It appears that even when working as a team, individual ground crew may have to routinely exert forces greater than 25 kgf in initiating movement of baggage trailers and, forces of up to 70 kgf during the movement of passenger steps. These are an every flight activity.

Dell (2007) associates the typical in-hold baggage handling activities and the context in which they occur to be comparable to some coal mining tasks. He quotes Stewart (2004):

> *"Materials handling tasks involve pulling, hanging, pushing and lifting of objects of different weights, shapes and sizes. Hundreds of these tasks are performed in underground coal mines each day, and often supplies are handled two or three times before end use."*

2 FINDINGS

2.1 LOAD WEIGHT CONSIDERATIONS

Stalhammar et al (1991) report that each of the nineteen handlers included in their study, were observed to lift an average of over 10 tonnes per shift. Culvenor (2007) reports an average cumulative load per handler per shift of 9 tonnes (maximum 13 tonnes). The link between cumulative daily load handled and injury risk is not well understood at present (Pinder, 1997). This issue has not been researched in further detail, but it is considered probable that any studies are more likely to consider tasks where the handling task is constant throughout the work period, rather than the sporadic intense periods of activity typical of baggage handling work. However, monitoring daily cumulative load, even broadly through the number of bags loaded, may be a useful means of judging risk level per individual worker.

In terms of a single baggage item weight limit, Dell (2007) presents a useful summary of the history and present situation. It is clear from this that a single item weight limit approached solely from the perspective of injury reduction will be considerably lower than any proposed so far by the industry. This is discussed further below in relation to the work presented by Culvenor (2007) and Douwes (2005).

At present, it is probably fair to say that from a passenger's perspective the baggage item weight limit situation is confused and inconsistent with different carriers and airports having different figures and arrangement for dealing with 'unacceptable' items. Historically, some airlines (Quantas, Ansett Australia, Air New Zealand) have agreed limits, so too have some airports (Heathrow, Edinburgh, Doha). These have typically been at the 32kg level, with a recommendation that items over 23-25kg are labelled as 'heavy'.

More recent information in Ground Handling International (Anon, 2006) suggests that British Airways have introduced a 23kg single item limit. Also, Ryanair have introduced a 10kg single item system, with excess baggage rates applying above this level. This is not a health and safety based initiative, but it is interesting that the market can work so as to create a health and safety benefit in this way. This does suggest that to some passengers at least, a reduction in the weight of each single item of checked baggage they are able to travel with is an acceptable change.

It is reported that budget airlines in general, using the internet as their main means of booking tickets, have seen advantages in being able to plan in advance for each passenger on each flight what the baggage load will be. By offering a pricing structure for baggage items and weight, including discounts for single items below a certain weight, or discounts for having no checked baggage, they may have been able to reduce average item weights as well as the total baggage load carried. However, we do not have any evidence to support this.

From a purely injury reduction view, Culvenor (2007) suggests that a single item weight limit reduction would need to go as low as 10kg or under. He presents an analysis using multiple 'tools' to derive a safe baggage item weight for the various handling operations involved in transferring an item from the make-up area to the aircraft (and vice versa). The average load weight derived is around 5kg which, according to the data presented below, is around one third of the actual average item weight. Dell (2007) applies the NIOSH lifting equation to those working outside the hold (it cannot be applied to those inside since the postures are too complex) and presents a weight limit of 6kg.

Culvenor (2007) presents some baggage weight information combined with data obtained from KLM in 1993 (Figure 1). The number of flights, aircraft types, and baggage items constituting this sample is not known.

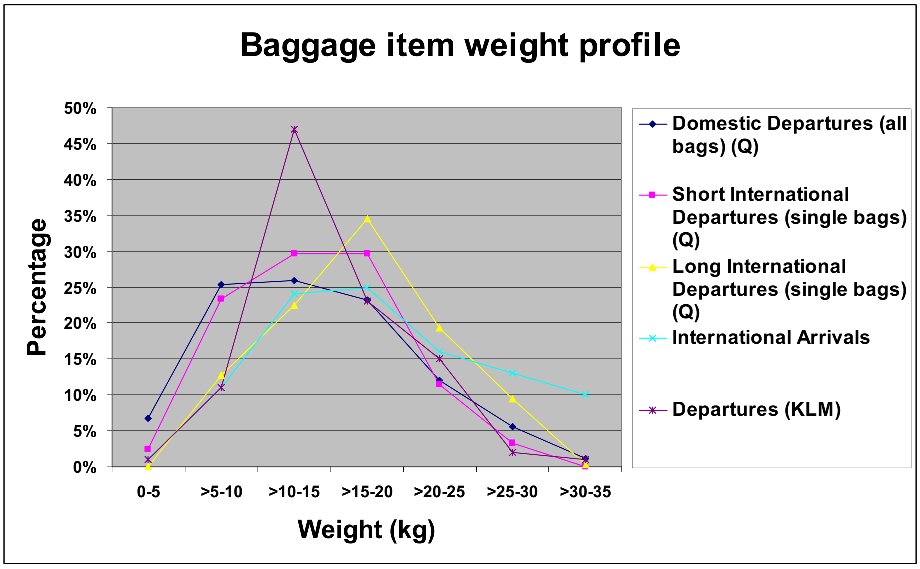

Figure 1. From Culvenor, ARTEX 2007

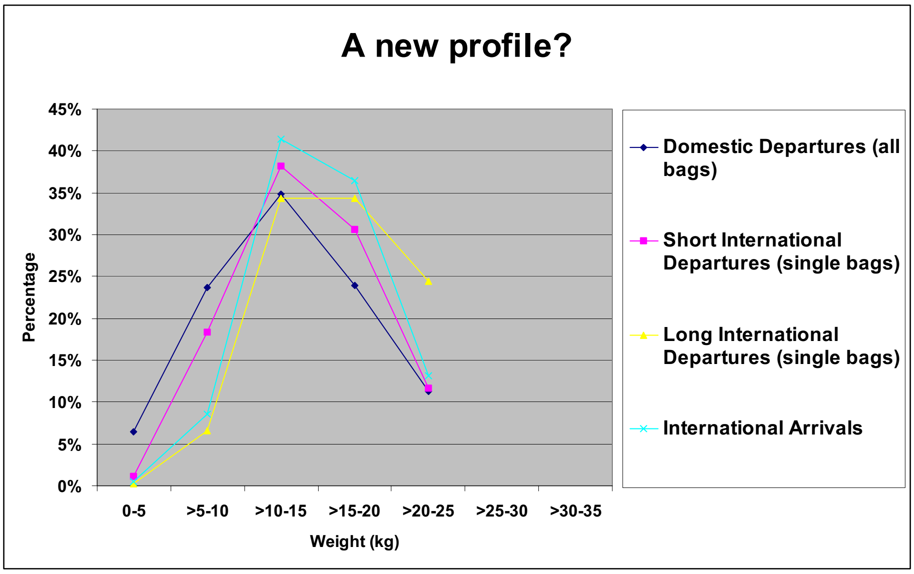

Figure 2. From Culvenor, ARTEX 2007

With this data Culvenor points out that introducing a single item weight limit of 23kg around 10% of the (heaviest) bags would be eliminated, and that in fact the average weight of items handled would be altered very little (Figure 2).

However, Dell (2007) notes the work of Davis and Marras (2003). In a laboratory study of trunk kinematics and spinal loading that examined the relative importance of the variables of lifting rate, load weight, load position and task asymmetry, they found that the load weight was the "*most important factor*" when controlling spinal compression forces when lifting. This supports the notion that lowering the single item weight limit will be a beneficial step in managing the risks to baggage handlers. It remains to be seen how the single item weight frequency distribution might be altered through a lowering of the limit to 25 kg or less.

Douwes (2005) in a TNO report as part of the initiative of the Schipol Ground Handling Committee presents the findings of work to assess the maximum recommended mass limits for manual handling of passenger baggage using the European Standard (BS EN 1005-2:2003, BSI 2003) and International Standard (ISO 11228-1:2003) methods. The author acknowledges that the two approaches to calculating the Recommended Mass Limit (RML) do not specifically include kneeling activities and so cannot be directly applied to the in-hold handling operations. The frequency distribution for item weight is not discussed. The 14kg mass figure for item weight presented is therefore assumed to be a mean. The resulting (mean) figures for the RML for the ramp based handling operations are in the range 3.2 to 5kg. These figures are based on the aim of protecting 85% of the working population (i.e. including female workers). The conduct of other 'heavy manual tasks' by the handlers is not included in the assessment, although these would tend to act so as to lower the RML further.

Introducing an international single item baggage weight limit of between 23 kg to 25 kg is a step that would have a positive effect in reducing the risk of handling related injury or ill-health to baggage handling workers, by eliminating the bags above this weight level that present the greatest risk. However, it appears that such a measure may not have a large effect on the average weight of items handled. It is difficult to quantify the likely amount of risk reduction. It will certainly not mean that the injury and ill-health risks associated with manual loading and unloading of baggage is automatically at an acceptable level.

2.2 BELT LOADER USAGE

Hoffman (1995) observed that the end of the belt by the baggage cart was typically set too low by workers, resulting in poorer postures than were otherwise necessary. This is a matter to be addressed through supervision, training and procedures. Hoffman also observed that these workers also tended to twist the trunk during their work, rather than stepping with the feet.

Egeskov (1992) reported that the worker at the hold doorway receiving items from the unstacking worker, or propelling items from the belt to the stacker were not considered to be at as high a risk of injury as the stacking worker. In certain circumstances it is possible for the worker performing this function to be stood stooped. Mital et al (1997) present capability reduction factors associated with handling stood upright in reduced headroom. These multipliers could be applied in assessing the risks in these situations.

There is little in the way of scientific evidence concerning the risks of musculoskeletal injury or ill-health associated with the 'propelling' of loads in this way. However, from observation, it is a highly dynamic action, and the internal loads generated in order to achieve acceleration of the load are likely to be very high. In addition, the action is usually carried out in a poor posture where the hands are above shoulder level.

Duignan and Fallon (2005) undertook a comprehensive study of aspects of manual handling at Dublin Airport (and others) over a period of 3 years, including ramp based handling with and without the use of mechanical assistance. They report results of three studies using heart rate, blood pressure and Borg Rating of Perceived Exertion (RPE) scales (Borg, 1970) as well as a posture measure (RULA, McAtamney and Corlett, 1993) for ramp based handling with and without belt loaders and also for the Sliding Carpet Loading System (SCLS) and the RTT Longreach in an aircraft mock-up (see next section for details of these devices).

For the in-hold workers the loading operation was found to be most posturally demanding. The external workers on the other hand, found the offloading tasks were the most demanding. For physiological and RPE measures, there was little difference for the external workers (there is little information relating to these measures for in-hold workers). The authors do state that the use of a belt loader was found to be less hazardous than non-use, but there is no detail of the comparison work.

2.3 AN ALTERNATIVE STACKING METHOD

Korkmaz et al (2006) – report a study investigating the benefits of providing baggage weight indication labels and of a systematic stacking pattern to minimize manual lifting of the heaviest baggage items (Figure 3). These two factors combine to produce a beneficial effect in reduced spinal loading. This study collected muscle activity using electromyography (EMG), trunk posture using a Lumbar Motion Monitor and applied force from a floor mounted force plate. There were 12 student subjects and the data was collected in a non-operational context. An EMG-assisted biomechanical model was used to process the data. Although the trial arrangements can be criticised for a lack or realism due to the subjects used, the uniform luggage used and the experimental context, the results indicate a clear potential for such a stacking approach to be employed operationally with worthwhile benefits.

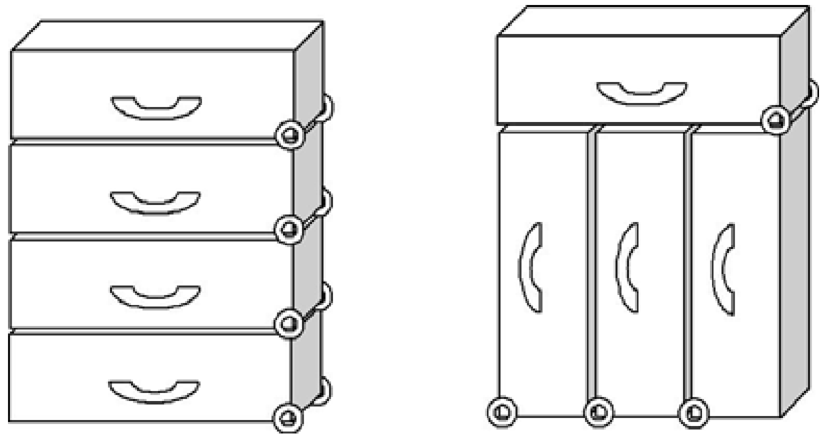

Figure 3. Alternate stacking method. From Korkmaz et al (2006)

Although there are clearly limitations in the reported study, it would appear that this approach could be employed by handlers for a proportion of the loading operation under many operational circumstances, and that this could offer a worthwhile level of risk reduction. It is accepted that the approach would not suit all circumstances, however, it could be a beneficial work method for the handlers to be familiar with, and that could be employed by them when the circumstances suit. It would therefore seem worthwhile for this to be trialled under realistic operating conditions to investigate how viable it is. If it is demonstrated to be a viable approach for on-line working, it should be further evaluated after a period of operational use.

2.4 MECHANICAL AIDS

These have in common the fact that they all avoid the need for handling functions to be performed manually. More specifically than that, these all avoid the need for a worker to be in the hold performing the function of moving baggage between the hold door and the stacking worker (and vice versa). This function has been acknowledged as presenting a lower risk of MSD incidence than the stacking work (Egeskov, 1992). However, some devices, the Extending Belt-Loader (EBL) based technologies for example, have been developed which reportedly significantly reduce the amount of manual exertion, lifting and supporting involved in the stacking and un-stacking operation. None of the systems described below have a fundamental effect on the fact that the worker needs to kneel, sit or squat in the confines of the hold. However, it is the combination of heavy handling while in a kneeling posture that presents the greatest risk of back injuries and ill-health developing. Reduced mechanical loading is also likely to reduce the risk of Lower Limb Disorders, specifically knee problems developing.

2.4.1 Moving hold floor systems

There are two known systems of this type, the Sliding Carpet Loading System (SCLS, Telair International, www.telair.com) and the Air Cargo Equipment Telescopic Baggage Cargo system (Dell, 2007). The latter appears to be known as the Telescopic Bin System (TBS) and is understood to have been bought-up by Telair, and is no longer in production.

These systems provide a moveable bulkhead and hold floor that can be positioned near the baggage compartment door so that one person can take the baggage from the belt loader in the doorway and stack the baggage against the moveable wall. When the stack is complete, the bulkhead and floor are moved backwards to create room for another stack of bags to be made. This cycle continues until the baggage is loaded, and is reversed for off-loading (Photograph 1).

These two mechanical systems have the benefit of eliminating one of the baggage handling operations – that of the intermediate worker moving the bags between the hold doorway and the stacking face, and vice versa. This is a significant benefit as the risks associated with this function are high. The baggage on and off-load with these systems is therefore a two-person operation, if a conventional belt-loader is used. Also, the benefit is effective at every destination, since it travels with the aircraft and there is no reliance on non-standard ground handling equipment. However, this technology does not help to improve the posture of the stacking / unstacking worker, or to reduce the manual lifting and handling operations associated with the stacking and unstacking function. The SCLS is reported to have been available for at least 20 years, with almost 3000 systems installed worldwide. Anecdotally, reliability of this kind of technology has been perceived to be problematic, and some carriers have removed existing systems in order to reduce the aircraft weight and therefore improve fuel efficiency. Telair report that this relates to the TBS system rather than the SCLS, and that reliability is very good (99.96%), and the weight penalty of the system is modest at around 160 kg to 250 kg, presumed to be per hold (personal communication with Fredrik Letzén, Telair International AB, 2008).

Dell (2007) reports literature and his own experimental study of these devices comparing the SCLS and the TBS system with no system. He cites several sources supporting the SCLS, but perhaps the strongest evidence is that presented by the Scandinavian airline Braathens SAFE (Johansen, 1995 quoted by Dell 2007), after Braathens installed SCLS in all 17 of their Boeing 737 fleet. After a year in operation, they report a 25% reduction in baggage handler sickness absence as well as a small reduction in baggage handling staff resource. In this author's opinion, the expected reduction in resource should be greater since one worker is eliminated from the usual team of three or four. Johansen (1995) also reports that there was no measurable increase in fuel consumption after installing the SCLS systems. Other supportive studies cited include opinion surveys of baggage handlers (Stokholm 1988, and Jorgensen et al 1987, quoted by Dell 2007).

Dell (2007) had attempted to evaluate the SCLS and TBS systems on non-operational aircraft, but had experienced difficulties with heart rate and oxygen consumption instrumentation due to electrical interference. A more controlled trial using a mock-up Boeing 737-400 hold compartment No.3 (aft of the wing) was conducted at the University of Ballarat. The aim was to compare the SCLS, the TBS system, and a control condition of 'no system'. The main difference between the three conditions is the size of the initial step created by the telescopic floors of the TBS (9 cm above hold floor), and the SCLS conveyor (2.9cm). Nine baggage handlers were used in the trials. Orthogonal video footage of the recreated handling task was recorded. Footage excerpts were analysed using the University of Michigan, 3D Static Strength Prediction Program (3DSSPP) and for reach distance. Ergonomists opinions on the activities were also sought. The results suggest that there was little difference between using the SCLS and no system, but that the TBS may present a greater risk due to increased reach distances observed. The SCLS and TBS have been studied by other researchers, and were reviewed by Dell (2007). The studies were all small and offer little in the way of robust evidence for the benefits to the stacking worker. This is not surprising however, since in reality the systems have little effect on the stacking task as such.

This technology appears to be relatively rarely encountered in the UK. An observation in relation to the health risks is that for some aircraft, such as the Boeing 737 series, where the hold doorway opens inwards and folds against the hold ceiling, the worker using the SCLS or the TBS is likely to be working in an area of further reduced headroom due to the door thickness. This was reported to be a confounding variable in Dell's (2007) study, since the mock-up of the door was neglected from the 'no system' trials.

The SCLS and TBS devices may also be used in combination with modified stacking regimes, such as that proposed by Korkmaz et al (2006) below. This could result in reduced handling risk (spinal loading) for the stacking worker, as well as eliminating one handler from the team working in the hold. These combinations have not been reported in the literature.

2.4.2 RTT Longreach

The RTT Longreach (Telair International) is a belt loader based device purpose designed to work in combination with the SCLS (also a Telair International product) and to deliver the baggage items to the position and level the item has to be stacked, and in theory to minimise the amount of manual handling required from the stacking worker (Photograph 1).

Cree and Kothiyal (2006) conducted trials using a mock-up hold and 10 experienced handlers in a comparison with the conventional belt-loader working practices. They used measures of rated perceived exertion (Borg, RPE) and posture analysis (OWAS, Karhu et al 1977). They found significantly reduced ratings of exertion, reduced amounts of pulling and pushing actions, improved postures (increase in good posture, 42% loading, 28% unloading) compared to the conventional use of the belt loader alone.

In their study investigating the use of the SCLS with the RTT (Duignan and Fallon 2005), the use of both assistive devices were found to be beneficial in reducing the frequency of occurrence of hazardous postures (RULA Action Categories 3 and 4) by 8% for unloading, and 34% for loading. Using both devices resulted in a 7.5% decrease in average heart rate compared to non-use. The RPE scores given by workers were also lower for the use of the SCLS with the RTT Longreach.

Photograph 1. The SCLS and RTT Longreach

(Source: Fredrik Letzén, Telair International AB)

Dell (2007) reports his own investigations of the RTT Longreach. These followed his experimental study of the SCLS and TBS system, but were conducted at a workshop of Occupational Health and Safety practitioners conducting a 'consensus' risk assessment.

Dell concludes from this exercise:

> *"While RTT Longreach Loader (RTT) does not fully eliminate the need for all manual work in the baggage compartment, it appears to make a remarkable difference to the ergonomic load on baggage handlers. Instead of having to lift bags from floor level up to ceiling height, the RTT was able to be positioned to deliver the bag at the height required. Accordingly, RTT seemed to significantly reduce the ergonomic demand for all lifts within the baggage compartment. The difference was most noticeable for the worst case lift, when lifting from below the waist, at floor level, to above head height when stacking in the top row."*

Dell (2007) also reports the supportive findings of Lusted (2003) who used the OWAS to assess the postures of 32 Qantas baggage handlers using the RTT Longreach. The results of this were compared with a belt loader when used in combination with a SCLS. The results showed some noticeable reduction in manual handling risk.

Overall, Dell (2007) remarks that the RTT Longreach seems to be a "*must have piece of equipment*" for use in loading ACE and Sliding Carpet systems.

It would appear that the RTT Longreach will work equally effectively with the SCLS, ACE or any other similarly functioning product. It would also appear that the RTT Longreach could be used to assist on loading and unloading baggage from some aircraft where no SCLS is fitted. These would include smaller aircraft such as the Embraer ERJ145 where there is a single hold door at the rear, sometimes in close proximity to the engines. The advantage would be that the internal worker would be able to have items delivered to/taken from them at a suitable level that is under their control. The external worker would not need to reach up to the hold to pass items in, but would be working with a belt-loader.

It is noted that the end portion closest to the worker is maintained horizontal at all times and it is fitted with roller balls. These are not driven but rotate freely. This portion of the device enables the handler to orientate the load as they require very easily during on-loads before placement in the stack, and also to orientate the load to suit themselves and/or the handler at the other end during off-loading. Because it is not driven it provides a short amount of ‘buffer’ time, for the worker to reposition the RTT Longreach in between handling items. Even though this time, depending on the spacing of the items on the belt-loader, may not be great, it does enable the stacking worker to position the device easily.

2.4.3 Rampsnake

The Rampsnake (Photograph 2) is a piece of ground handling equipment that has been designed to reduce and assist with the manual elements of bulk loading. The authors classify the Rampsnake as extending belt-loader (EBL) technology, along with the other known devices of this type, the Powerstow and Mongoose. It replaces a conventional belt loader and incorporates an extending powered conveyor section, and provides some other important features. It enables baggage items to be transported directly between the worker at the stack in the hold and the worker at the baggage cart, and vice versa. In the hold it also provides an adjustable raising section of conveyor (up to 0.8 m) to assist with the transfer between belt and stack. In addition, at the baggage cart end, it provides a height adjustable and extending section of conveyor. The aim is to reduce as far as possible the amount of manual lifting and supporting required in the transfer of items between baggage carts and the stack within the aircraft hold. The intention is that predominantly only pushing and pulling actions remain. Compared with the conventional use of a belt loader, it also removes any need for the intermediate worker located within the hold doorway. It is therefore a two-person operation.

Photograph 2. The FMC Rampsnake

(Source: http://www.fmctechnologies.com/upload/rampsnake.pdf).

Koelewijn (2004, 2006) reports a study undertaken to evaluate the effectiveness of the Rampsnake handling equipment at Schipol Airport for KLM. This was a comprehensive study recording the following variables:

- Heart rate;
- Borg, RPE;
- Working posture (OWAS);
- Push/pull force measurement.

Average heart rate when using the Rampsnake seems to be reduced in comparison to the conventional belt-loader method, and by association so is energy expenditure (except for the in-hold unloading). Using heart rate reserve to correct for age and resting heart rate differences, Koelewijn reports that the situation remains similar. These differences are however, not statistically significant. As well as comparing the Rampsnake work situation with conventional belt loader usage, an interesting additional element of the analysis looked at the differences between loading with and without a belt loader. The unloading operation in the hold has a greater heart rate reserve when a belt loader is used, than without. However, looking at the ramp handling operation, the converse is true, and the use of a belt loader produced a lower heart rate reserve.

For ratings of perceived exertion (Borg, RPE), the Rampsnake has a significantly lower overall average rating of 2.5 (moderate to somewhat strong) compared with 3.3 (somewhat strong to strong) for using a belt loader. Looking at the averaged scores for each subject, the maximum rating is 5 for use of a belt loader. This is surprisingly low, although the scores for the non-hold tasks will be expected to have masked the likely peak ratings that might be expected for the in-hold activity. It would be interesting to see this level of analysis presented.

A time-based sample (every 15 seconds) of video footage indicates that the incidence of lifting is significantly less with the Rampsnake (5% of samples) than it is when working with conventional aids (28% of samples). This reduction in lifting was not compensated for by an increase in pulling tasks. Similarly, there was significantly less lateral flexion and rotation of the trunk with the Rampsnake (23% of samples) than when working with conventional aids (41% of samples). Also, working with the arms at an unfavourable angle (upper arm(s) at an angle >60 degrees from the trunk) is significantly less likely when working with the Rampsnake than when using conventional working aids. Not surprisingly, for leg posture, there was no significant difference between working with the Rampsnake and working the conventional way, since kneeling is the routine posture adopted for both methods.

Only pulling forces were measured due to the difficulties in accurately recording the push force applied to a baggage item in the hold. Pulling requirements are simply much easier to establish. The equipment used was identical to that used by HSL/E field staff (a Mecmesin handheld Force Gauge), and it is assumed to have been within calibration. The operations measured were therefore only those where pulling is an element, unloading in the hold (pulling off the stack in the hold), and loading on the apron (pulling off the stack on the cart). No significant difference was found between working with the Rampsnake and conventional means. There were however, substantial differences in the forces measured between individuals. This is believed to be attributable to working technique and pulling speed.

Koelewijn's overall conclusion is that the use of the Rampsnake is beneficial and recommends it be adopted by KLM. Although not a 'source' solution in that it does not avoid the need for the manual operation, it has significant advantages. A cost-benefit analysis for KLM suggests that the annual savings in terms of absenteeism costs would be in the range of Euro 0.5M to Euro 2.1M. We have been informed through personal communication, that KLM have ordered 39 Rampsnakes for use at Schipol Airport.

2.4.4 Powerstow

This is an EBL type device very similar to the Rampsnake in function in that it provides an extending powered conveyor from a belt-loader type device running in through the hold door right to the working point within the hold (Photograph 3). It is based upon a conventional belt-loader base as a complete product, but an important difference from the Rampsnake is that the extending conveyor element can be retrofitted to existing belt-loader bases. However, to fit the extending conveyor component requires some upgrading to elements of the belt-loader base, due to the increase in weight. Although functionally very similar to the Rampsnake, a noticeable difference is that it uses individual powered rollers in the extending conveyor, rather than the Rampsnake's small powered conveyor units. Like the Rampsnake, it also has the facility at the end of the extending conveyor to assist with the raising of baggage items from hold floor level (or vice versa). Koelewijn's (2004, 2006) findings for the Rampsnake are considered to be directly relevant to any EBL with similar features. At the time of writing, the Powerstow does not have the height adjustable extending conveyor section at the baggage cart end, for the worker transferring between the baggage cart and the belt. Without this feature, the lifting task and the risks are considered to be identical to that for the use of a conventional belt loader.

Photograph 3. The Powerstow roller track.

(Source: Helle Rohde Neilsen at Powerstow A/S)

2.4.5 NMC Wollard Mongoose

Another EBL device has been developed by NMC Wollard in the USA (Photograph 4). Through personal communication (T. Lange, NMC-Wollard, April 2008), we have photographs and technical details showing that this is very similar in function to both the Rampsnake and the Powerstow. Like the Powerstow, the basis of the product is a conventional belt-loader. It has an extending conveyor that reaches laterally into the hold from the door. The loader end can be raised to an unspecified level, but this is reported to mean that it has the capability to be used to off and on-load a Boeing 777 series aircraft. Like the other EBLs, it can also be used as a conventional belt-loader. At the time of writing, the Mongoose does not have an adjustable, height adjusting or extending conveyor section for the interface with the baggage cart. At the cart, the handling operation will be identical to that for a conventional belt-loader. The device has now been demonstrated and marketed at Airport Expo 2008 in Las Vegas in April 2008. At the time of writing there is no publicity material available on the company website (http://www.nmc-wollard.com accessed May 2008).

Photograph 4. The NMC-Wollard Mongoose.

(Source: Tom Lange, NMC-Wollard Inc.)

2.4.6 Mallaghan LBT90

From initial observations it appears that this device may enable improved handling postures compared to direct to hold and other loading and unloading approaches. The manufacturer's promotional material (Mallaghan, 2007), indicates that the device can reduce the number of crew required during the off and on-load process. This will be in comparison with the typical loader method, where one handler will be required at the hold door to move items between the belt and the stacking handler, and vice versa. When using the Mallaghan LBT90 (referred to colloquially as a Mallaghan), the one or two handlers on its platform fulfil this function during on-load . The manufacturers also claim that the operation can be done more quickly, but we have no evidence for this at present.

This unique device effectively replaces 3 items of ground support equipment (GSE) on the ramp, the baggage carts, the tug to pull them, and the belt loader (there is a mini-Mallaghan that is a smaller, towed version). There are important issues of compatibility with aircraft types and especially with airport infrastructure. The baggage hall, its conveyors and its access and roadways all need to be designed to accommodate the Mallaghan LBT90, otherwise its effectiveness is significantly reduced, and further risks may be introduced. More work is needed to establish the extent of the Mallaghan LBT90's capabilities in terms of the range of aircraft it can be used with, and in undertaking a more detailed appraisal in relation to the manual handling risks. The Mallaghan LBT 90 is shown in Photograph 5.

Photograph 5. Mallaghan LBT90

(Source: Mallaghan Engineering Ltd.)

2.4.7 Bulk baggage carts

The latest development in the area of ramp based baggage handling comes from a collaboration between Copenhagen Airports, CPH Design, FKI Logistex and SAS Ground Services (personal communication, February 2008). Named the Big Bag Box (BBB), this ongoing project appears to be succeeding in addressing the repeated manual handling of items associated with moving baggage between the airport infrastructure and the baggage cart and its partner equipment, the Rampsnake EBL (and vice versa). The target aircraft for the concept are reported to be the Boeing 737, MD80/90 and Airbus 319 families.

The equipment forms a functional link between the airport automatic make-up infrastructure and the ramp. It is essentially a baggage cart fitted with a set of enclosed and angled roller bed shelves onto which the airport infrastructure can discharge baggage items (the box). The whole enclosed set of shelves, with individual shelf doors at each end, can be rotated to facilitate the gravity discharge from, or feed to, the shelves. At the ramp, the shelves are accessed using the Rampsnake's tail-end adjustable and extending conveyor (Photograph 6). The baggage items will discharge automatically by gravity from each shelf accessed due to the angle of the roller bed. For off-loading the aircraft, the baggage items are fed directly into each shelf unit (from the other end) again with the Rampsnake tail conveyor being operated by a ground handling worker. There are key benefits at the baggage cart make-up area, where the make-up process is being automated and is planned to operate unmanned. Clearly this requires considerable expenditure in terms of automating the baggage sorting and make-up process within the airport infrastructure. Human intervention is still required between the BBB and the Rampsnake, both during on-loads and off-loads. For full benefit, the BBB also requires an automated system to discharge its load to at the arrivals/transfer belt.

Photograph 6. The Bulk Baggage Cart or 'Big Bag Box'

(Source: Jan Poulsen, SAS Ground Services)

2.5 THE EFFECT OF HANDLING WHILE KNEELING

Yang et al (2005), with the same group of authors as Korkmaz et al (2006), reports a study using a very similar experimental approach, but concerning a more fundamental issue: The differences in spinal loading when handling in a kneeling posture compared to standing. The most importance difference while kneeling appears to be in the increased anterior-posterior and lateral shear forces (by 65-157%) rather than disc compression.

2.6 OTHER NOTABLE ISSUES

2.6.1 Training and back belts

The use of back support belts has long been a controversial issue, and the HSE line on the subject has been to advise against their use. Although this issue is certainly not considered to be in the mainstream of risk reduction in this sector, these findings help to reinforce the message. Smidt (1998) and Reddell (1992) both conducted relatively large scale (n=282 and n=642) studies of baggage handlers receiving back belts, training, both, or neither, at KLM and American Airlines respectively. They both found that neither intervention offered any benefit.

2.6.2 Resting laying down

Dell (2007) cites two studies by Leskinen (1991) and Stalhammar et al (1991) respectively, both report that even short periods of rest spent laid flat would improve spinal disk nutrition and that this should in turn improve resistance to injury. However, Dell (2007) reports that although since the early 1990's many airlines have provided the facility for handlers to rest lying down, these facilities are underutilized (Cree 2003, quoted in Dell 2007), and as a consequence the proposed benefits have not been realised in terms of injury and ill health reduction. This is however, not a control measure that is familiar to the researchers in terms of the GB situation.

2.6.3 Fundamental change to the process

In terms of achieving a change in baggage handling operations, Dell is critical of H&S regulators worldwide, and uses the GB as an example (Tapley and Riley, 2004), because HSE do not pressure the industry enough for fundamental change (and large improvement), but tend to make recommendations that only 'chip away' slowly at relatively easy to solve issues and consequently achieve relatively small gains. The author would however say that the need for fundamental change has been identified in previous work, but in order to be realistic, and to avoid losing credibility with the industry, this has not been a priority short-term recommendation.

Dell (2007) rightly makes the point that many interventions proposed are at the bottom of the hierarchy of hazard control that is fundamental to health and safety, and as a consequence they fail to have a significant effect.

Culvenor (2007), like Dell, pushes for the fundamental change that is required to gain a step reduction in the injury risk associated with ramp-based baggage handling. He suggests that while the approach of trying to achieve small changes to a number of elements will have a beneficial effect, what is needed is some real innovation, and some pressure for change at higher levels. He presents a sphere of influence model ranging from the societal level with the 'travelling public', inward to the level of the baggage handler or handling team. Change at the centre is easiest to achieve, but has least impact. An example of a change requiring influence at higher levels is that of the baggage item weight limit. This will require influence at the societal level to gain acceptance for it, and over time, compliance.

3 CONCLUSIONS

There is good evidence for the benefit of some mechanical assistance devices, both GSE and in-hold systems, in terms of reducing physical workload, manual handling and MSD risks associated with baggage handling work on the ramp.

The strongest scientific evidence is for the Rampsnake in reducing the manual handling injury risks to baggage handlers (Koelewijn 2004, 2006). However, these findings are considered relevant and directly applicable to EBL type equipment generally, i.e. to the Powerstow and Mongoose. The work reported that examines this technology is good quality science, employing a robust approach. There therefore appears to be little need for further work to support this technology on manual handling grounds. However, there are operational matters that need to be addressed. In particular, we do not at this time have evidence for EBL practicability of use in the 25 minute turnarounds that are typical in the low cost sector where the use of Boeing 737 series and Airbus A319 to 321 aircraft are prevalent in GB.

EBLs with adjustable tail-end (cart) conveyor sections offer additional benefits, and present arguably the most complete solution presently available, as they reduce the manual handling load for the worker on the ramp transferring between the cart and belt (and vice versa). However, the fact that some EBLs do not, at present, provide this function is considered less important than the manual handling benefits that they offer the in-hold workers.

However, the bulk baggage cart (BBB) approach requires the use of the Rampsnake to create a more complete solution in either avoiding or significantly reducing the manual handling involved in the transfer of baggage from the airport to the aircraft and vice versa.

Other mechanical assistance products also show good evidence. The SCLS and TBS devices in combination with ‘advanced’ belt loader type products like the RTT Longreach are considered to offer comparable benefits to the EBL technology in terms of the reduction in manual handling for the in-hold stacking or unstacking worker. When the worker is skilled with the equipment, the manual handling is much reduced, and it is mainly pushing, pulling and guiding of baggage that is required. Of course other postural aspects associated with working in the hold remain.

Quantitative information on the manual handling risk factors as they relate to use of the Mallaghan LBT90 is lacking, but at face value they appear to be a viable alternative approach for fast turnaround working because they are currently in use in the low-cost sector. The circumstances to which the Mallaghan LBT90 is most suited, and those where it is less beneficial remain to be investigated.

Alternative bag stacking methods such as those described and investigated by Korkmaz et al (2006) appear to be viable operationally, and offer some modest but significant reductions in risk for the handler. They are yet unproven in live operations.

4 KNOWLEDGE GAPS AND RECOMMENDATIONS FOR FURTHER WORK

4.1 THE PRACTICALITIES OF USING TECHNICAL AIDS IN RELATION TO AIRCRAFT TYPES TYPICALLY ENCOUNTERED BY GB BASED BAGGAGE HANDLERS

We have good information concerning the range of MSD risks presented by ramp-based manual baggage handling operations for Boeing 737 series and Airbus A 319 aircraft. We do not have observational evidence of the range of other aircraft types that typically require bulk loading of hold baggage. The risk reduction measures applicable for use with 737 series aircraft (and similar) may not be practical to use for a number of reasons. HSE cannot develop comprehensive and credible policy and information for the industry without being better informed.

- **Gather observational data on the range of aircraft typically encountered in order to better understand the practicalities and realities of using belt loaders and other risk reduction measures.**
- **Establish the applicability of EBL and other mechanical handling technology in the GB low cost sector.**

4.2 BAGGAGE ITEM WEIGHT FREQUENCY DISTRIBUTION

At present there is relatively little information concerning the nature of the baggage item weight frequency distribution. It is important to establish the average weight and the range of item weights handled. We understand that the frequency distribution for item weight is likely to vary according to the carrier, airport, route, time of year, etc., but without this information it is difficult for anyone to make truly representative risk assessments for baggage handling operations. We can only work on the basis of the average and worst scenario situations.

- **We need to have access to this information, and require industry cooperation in order to gather it.**

4.3 EFFECTIVENESS OF THE MALLAGHAN LBT90

We need to analyse suitable footage of the Mallaghan LBT90 in operation in order to be able to make a comparison of the postures adopted with those for standard belt loader use. A suggested approach is to use OWAS to enable comparison with reported studies.

- **A postural analysis of Mallaghan LBT90 use needs to be undertaken.**

4.4 BAGGAGE STACKING METHODS

Korkmaz et al (2006) describe the benefits of an alternative baggage stacking method. This appears to offer significant advantages in terms of reducing spinal loading. This needs to be combined with clear indication of item weight (in bands) to be most effective. It has not been investigated in operational conditions.

It is envisaged that the approach may be applicable in a limited set of circumstances, and for a proportion of any baggage load, but nonetheless the benefits are there, and if the approach can be adopted to any extent during loading activities, this will be beneficial. It appears to be a practicable means of reducing the risks.

- **We need to investigate the practicalities of adopting this method in operational conditions, and the extent to which it can be adopted.**

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Reducing the risks associated with the manual handling of air passenger baggage for narrow bodied aircraft

Literature review update

This report is an update of the review for ramp-based baggage handling related literature undertaken in 2005 (Tapley and Riley, 2005). The aim of this review is to present information relating to alternative methods of loading narrow-bodied aircraft that reduce the manual handling related injury and ill-health risks to the handlers, and to identify knowledge gaps. This was used to inform subsequent work at East Midlands Airport in 2007/2008 (Musculoskeletal ill-health risks for Airport Baggage Handlers: Report on a stakeholder project at East Midlands Airport - RR675).

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RR674

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