Safe Design of a Parcel Sorting System

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Abstract. Australia Post is investing in a new parcels network, including new sorting systems in Melbourne and Sydney. With safety as a key culture pillar of the corporation, safety was comprehensively considered from the initial scope of the Future Parcels Network Program through design, validation and verification, and implementation of new parcel sorting system. This case study describes the process followed to ensure a safe design through to realisation in an environment requiring speed of action, accountability, collaboration and customer focus. The case study focusses on the Human Factors/Ergonomics (HFE) approach to efficient system design to reduce manual handling risk, including design validation.

Keywords: manual handling, safety, systems design, safe design, parcel sorting

1. Global Situation Analysis

1.1 Parcel Sorting and Safe Design

The on-line purchasing revolution ramped-up it's demand during the late noughties to the point where Australia Post's capacity to sort parcels maxed-out in October 2011, well ahead of the forward planned design capacity of their network. The volumes in the existing network had allowed for Parcel Delivery Centre based sort plans. However, the growth was placing a strain on downstream distribution systems and a deeper sort (to vans) and product streaming was required. Initial new network designs were looking forward to at least 2020 volumes.

As a result of this need for a deeper sort and greater sorting capacity, Australia Post is investing an initial $595 million (AUD) to build a world-class parcels network. New sorting systems have been designed and implemented in Melbourne and Sydney. The sorting systems typically handle 25,000 and 33,000 parcels/hour in Melbourne and Sydney respectively, more than doubling capacity.

The parcel sorting system design project was, amongst others, based on the concept of Safe Design which is a detailed “up front” consideration of potential safety issues that compares well with ergonomic systems design as developed by Singleton. Safe Design also seeks to achieve certain safety outcomes through the design, and performance measures are set for those outcomes. The concept is not new and during the late 1990s, many safety practitioners promoted the idea of building-in safety “up front”. The savings are significant, because it is usually expensive to retrofit safety after a project is completed. Taking the time to think through systematically what might go wrong at the design stage enables a range of options to be considered in determining a solution. Options to address issues are usually limited once a system is built.

The concept has developed from thinking about safe design for products and systems, through to the safe way a building or bridge construction may be implemented to prevent harm both during and after construction (FSC, 2007). We see safe design in contemporary vehicle design; such as passive and active crash protection. Often a great design or “form” can be thwarted in its execution through poor or late consideration of safety elements and this significantly impacts the “function”. Considering usability and ergonomics of plant and systems as part of the design is also likely to provide for greater productivity in the longer term (Nelson, 2000).

Sorting processes usually include manual handling tasks. An interesting example of a systems redesign can be found in airport baggage handling (Lenior, 2012). Pikaar (2008) stated that manual handling can be reduced, but not be avoided for comparable settings at baggage handling. Parcel weight and parcel handling frequencies may cause complaints, injuries and a loss of productivity through industrial disputes and disruption in the event of injury.
1.2 Areas of Risk

At the same time, Australia Post’s Future Parcels Network project recognised emerging challenges with an ageing workforce (average age 49 years) and the need to fit the new equipment and systems to the capacity of a diverse workforce. An enterprise wide safety cultural transformation was also honing-in on the prevention of Serious Injuries and Fatality (SIF) risks. SIFs are low likelihood events that have catastrophic consequences; often game changing. Based on these two driving concerns, four areas of the new automation system design were called out for proactive prevention:

1. Segregation of pedestrians and powered Load Shifting Equipment (LSE). There had been a number of near miss incidents at the Melbourne and Sydney parcel facilities and a higher order control was needed to prevent a disaster. Within Australia, LSE is known to be a significant cause SIFs (ABS, 2013, Safe Work Australia, 2012).
2. A 50 percent reduction in the number of manual handling events. Manual handling accounts for 46 percent of injuries at these parcel facilities, and reducing manual handling risks will pay for the cost of the manual handling risk prevention measures over a two to three year period. Reducing manual handling also has productivity benefits but this is difficult to quantify at this early juncture.
3. A reduction as far as practicable in the need for high risk work at height by maintenance staff. Falls from height are a known SIF risk (Safe Work Australia 2015) and working from scaffolds, boom lifts and similar is much slower and more awkward than working on a dedicated platform or floor.
4. A reduction of 50 percent in LSE and a reduction in truck movements so far as practicable.

In addition to these key prevention focus points, Australia Post considers system design elements including ergonomics, machine guarding, electrical safety and other general safety and productivity design aspects. This case study focuses on the reduction and control of manual handling events.

1.3 Containerisation vs Loose Load

Australia Post has an unit load approach to the movement of mail and parcels. Mail and parcels are stored and transported in a containerised cubic metre metal cage called a Unit Loading Device (ULD). The project questioned whether this unit load approach was still the right approach in the current environment. A pilot exercise was conducted to consider the place of “loose load” in Australia Post for general parcels handling. Loose load involves manually loading and stacking parcels directly into the back of a semi-trailer or container. The pilot demonstrated that there was a place for loose load in long distance transport such as the East to West coast of Australia or North to South. However, as loose load requires repetitive manual handling from floor to near ceiling of a semi-trailer or container it presented the project group with a unique challenge in ensuring that work could be performed safely.

1.4 The Weight of Parcels

As with any parcels project, an analysis of parcel dispersion data (weight, size and other characteristics) identified a number options available to optimise the safe parcel handling work methods. Postal organisations tend to have parcel weight dispersions biased to the lighter end. Indicative median weights are usually under 2 Kg with 90 percent less than 10 Kg and 99 percent under 23Kg. Size attributes are similarly distributed with median parcel volumes less than a shoe box (cubic) or satchel (flat packet) in size.

2. Safe Design Approach

Over the past 20 years Australia Post has evolved a comprehensive suite of engineering specification for mail and parcel processing equipment. Based on experience with vendors, incident investigations and reviewing safety literature, the engineering specifications cover a range of safety related matters including ergonomics, focus is on the following:

- Musculo-skeletal Body Stressing [biomechanics]
• Energy Expenditure and fatigue
• Cognitive considerations
• Anthropometry [especially height and reach differences between workers]
• Hand clearance
• Lifting space restrictions
• Standing and/or sitting and working operator postures
• Loading and clearing heights
• Operator controls and displays; visual and audible indicators [interface]
• Work study data per operational function.

In addition to requirements for the items above, some design process related requirements are specified. Of particular interest for HFE is Australia Post’s mandatory independent validation and verification of the engineering design. To this effect, the parcel sorting equipment vendor had to provide a third party ergonomic assessment certifying the suitability of the equipment. This certification approach is a real winner with employees and enables a good governance approach within the Safety Management System framework.

In addition to the ergonomic assessment, the organisation invested heavily in the following:

• Collaboration and engagement with Melbourne and Sydney Parcel Facility’s Expansion project teams;
• Overseas site visits to review best practice;
• Workstation mock-ups with the vendor;
• Integral involvement of ergonomists as part of the design team;
• Internal safety teams;
• Operational Managers (especially those who have investigated incidents); and
• Consultation and Engagement with the workforce and unions including:
  o Regular briefings and updates provided at National, State and local facility consultative forums;
  o Local working groups established at each site with Health & Safety Representatives (HSRs), Authorised Union Representatives (AURs) and staff;
  o Extensive consultation with operations and technical site representatives during Critical Design Review (CDR);
  o Union site visit to Vendor’s test loop in the Netherlands;
  o Union and staff briefings on the outcome of CDR and Factory Acceptance Testing (FAT);
  o Involvement of site representatives in acceptance testing, development of Risk Assessments and Safe Operating Procedures, and development of Engineering Safe Work Instructions; and
  o Development of safe work durations and work rotation arrangements.

The independent ergonomic found that the client engineering specifications had different levels of detail. Some ask for detailed measurements (clearances and energy expenditure), other have a much more general level (postures and qualitative reference to work organisation). The independent ergonomist was able to add value by being specific about job load, task duration and local work organisation, and being more specific about certain considerations such as reach (optimal reach range, maximum reach range, horizontal reach). The independent ergonomic assessments considered all person machine interfaces.

Biomechanical analysis through the application of NIOSH Manual Lifting Guidelines (CDC, 1994) resulted in the establishment of Recommended Weight Limits (RWL) for each new task type. NIOSH is not ideally suited to high frequency sorting or manual unloading tasks, but at the rates used in the new parcel sorting system NIOSH was still appropriate.

Past anthropometric measurement indicates that the Australia Post population size is consistent with the US population (anthropometry), but additional consideration was made for slightly lower stature workers.

The project team were able to draw on the experience of internal safety and ergonomics consultants who had been involved in past projects and could therefore inject safety specifications into the engineering requirements to address known issues. This is an important part of safe design. In addition, having an ergonomic involved at all stages (initial tender and specification, assessment of proposals from vendors,
preparation of contract specifications, critical design review, factory acceptance test and site acceptance test, any previously unseen human factors issues could be addressed before the equipment was built. It was the ergonomists who were identifying issues and drawing them to the attention of the project team. The team would then look for design improvements. It is important to note this ergonomic assessment process (not a post implementation review process) resulted in significant design innovation including:

- Man rider platform on extendible reach conveyor using a vacuum lifter (the first of its kind), (see figures 1 to 4 including contrast with traditional loose load);
- Adoption of Vacuum lifters for tasks involving repetitive heavy lifting in excess of RWL;
- Direct load automation to reduce manual handling events (see figures 5 and 6);
- Adoption of height adjustable trolleys at indirect load chutes for parcels over RWL (see figure 7); and
- Sort to light and double scan for parcels over 16Kg requiring 2 person lift/slide with the assistance of a powered height adjustable trolley.

3. Safe Design Outcome

3.1 A fifty percent reduction in manual handling events per parcel

3.1.1 Observation of work methods

Through observation of the manual movement of parcels by the workers, it was evident that employees were using non-preferred handling practices to reduce the carrying of parcels. It is natural for workers to conserve energy and moving the whole body adds to energy expenditure. Lightly throwing lighter non fragile padded parcels is much easier and it is parcels under 2 Kg that were often thrown; usually in either an underarm style or a lob, not a forceful pitch. The immediate thought is to sort these small to medium and lighter items directly to a ULD, bag or container using automation. Mis-handling parcels in this way presents other musculo-skeletal risks where it is repetitive and sustained.

3.1.2 Potential for automation to reduce manual handling events and minimise mis-handling

Small parcels were already being sorted directly into bags and ULDs at sorting machines designed and built by Australia Post. Following a review of similar direct containerisation processes in other countries, it was clear that the process could be increased to medium size parcels with the right equipment. Finland Post successfully direct load parcels up to 3Kg without customer complaint and through trials with our automation provider, a process was developed to suit our dispersion and direct load small to medium parcels. Not all parcels are suitable for direct load to a ULD as fragile items or boxes of wine must still be handled by a person. Above a certain size, it was noted that the fill rate in the ULD became less efficient so a size limit needed to be applied. So high were the number of small parcels that even with direct load parcels removed, the median parcel weights remained low.

3.2 Managing the residual manual handling

3.2.1 Indirect Load and the use of a height adjustable trolley

The remaining parcels that could not be direct loaded or loose loaded for interstate transport could still be transferred by manual lifting to ULDs at an indirect load chute. Fortunately with the median parcel weight of the remaining dispersion remaining low, there were some suitable manual handling options available for indirect load.

After a critical design process working with the parcel sorting equipment vendor, and before a factory acceptance test, the design was provided to a third party ergonomist for review. Utilising the NIOSH methodology, the independent ergonomic assessment identified an RWL for the indirect load process around 10 Kg with a two hour break and task rotation. This catered for well over 90 percent or parcels. For the parcels above the RWL, a number of options were considered and the staff liked an easy to use height adjustable trolley to assist with transferring parcels by sliding (chute to trolley to ULD). Staff can seek assistance from a co-worker to handle bulkier or large size items by trolley. Thus a safe design was determined before the final design was signed-off.

3.2.2 Managing occasional heavy items
Australia Post has a long standing single person lift weigh limit of 16 Kg. Parcels over 16Kg are identified by the system's dimension-weigh-scan equipment and the operators are notified by visual signal when they scan the parcel at the chute that a two person lift/slide is required with the assistance of a powered height adjustable trolley. The combination of eliminating parcel-throwing, using the trolley where parcel weights exceed the RWL and the two-person lift (with the trolley as required) is a significant improvement in the manual handling controls compared to previous system of work. The new system of work caters well for the ageing workforce, especially with task rotation every two hours throughout the day to vary muscle usage and reduced effort required for manual handling. Also, it is worth noting the importance of being able to include workers on rehabilitation return to work (RTW) programs at the new workstations. RTW workers often have weight and duration limitations; 10 Kg is a common limit noted by Australia Post. The new work systems facilitated easy inclusion of rehabilitees and there are significant compensation savings from early return to work following occupational injury.

3.3 Use of Vacuum Lifters

3.3.1 Manual Induction of fragile and non-invertible product

Most parcels are transferred from a ULD to the sorting machine by a gentle ULD inversion machine (no manual handling). For parcels that are fragile or cannot be inverted, manual induction is utilised. Based on the RWL determined by the independent ergonomist for manual induction, work practices including two-hourly rest break and task rotation between lifting and sliding or non-lifting tasks is provided (see example in figure 8). At selected manual induction workstations contemporary single handed vacuum lifters have been installed.

3.3.2 Loose Load of parcels above RWL

As with the manual induction, vacuum lifters have been installed on the loose unload reach conveyors to reduce body stressing. The vacuum lifter is attached to a height adjustable overhead gantry fitted to the end of the reach conveyor that has an operator platform. The ergonomic assessment utilising the NIOSH methodology identified manual induction and loose load out as having very low RWLs for the desired sort rate. By utilising a vacuum lifter for heavier product (or in case of loose load out, from below knee level), a more productive sort rate was possible. The vacuum lifters in these applications has significantly reduced the risk of injury, especially to an ageing workforce.

The use of a height adjustable worker platform on the loose load conveyors means that the staff do not need to lift over face height and there is no need to utilise a step stool or ladder to fill the upper part of a trailer.

3.4 Review after implementation

Melbourne and Sydney are in operation now. In a subsequent installation of the loose load out operation in Perth, some improvements were considered. The reach conveyor platform supplier used two hydraulic lifters (one either side) resulting in less platform twist and movement than a single centre mounted lifter.

Initial work rate estimates used for planning purposes at Sydney and Melbourne were higher than could reasonably be achieved considering a NIOSH assessment. Not everything in HFE is easy in a major project and is never "ideal". It has to be understood that the parcels industry is highly competitive and some nice to have features are just not practicable. More space in the equipment layout would be very helpful if practicable,

4. Conclusion and discussion

The benefits derived from the approach of "safety by design" in the first phase of our parcels network modernisation has led to:

- An increased use of deep sort direct load to ULD (containerisation);
- The adoption of new NIOSH RWL based work practices and processes for indirect load, manual load and loose load;
- Utilising ride-on platform based Loose Load with vacuum lifters addressed the manual handling risks but there is an impact on productivity (slight decrease in the number of parcels unloaded per hour);
The risk of injury from the parcel sorting and handling operations has been significantly reduced, especially the Serious Injury and Fatality (SIF) risk (noting falls from heights and LSE pedestrian collisions); Early indication is showing a reduction in incidents compared to a similar period for the old system of work; and

The NIOSH influence on job design including task rotation has provided an effective way to reduce manual handling risks but with some impact on productivity.

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References
http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/6102.0.55.001Chapter252013

Figure 1. Loose Load (in) height adjustable reach conveyor with gantry mounted vacuum lifter rated to 40 Kg. Note extendable air supply duct.

Figure 2. Loose Load (in) Inside a container using vacuum lifter below knee height. Gantry is also height adjustable. Note sensors on top of gantry to stop unit striking roof or door.
Figure 3 (Above). Traditional loose load without a height adjustable platform. Note the orange elephant footstool and low light in the upper area.

Figure 4 (Below). Vacuum lifters capable of lifting 40kg parcels.

Figure 5. Direct Load sorting system showing cross belt parcel sorter, direct load chutes and deep sort ULDs. Parcels smoothly ejected from the moving cross belt slide gently across the chute into the ULDs either side.

Figure 6. Direct Load operator work area showing parcel smoothing at deep sort ULDs prior to initiating removal by robotic ULD handling system. Correctly dimensioned guarding prevents unsafe access to or entrapment by moving machine elements.
Safe Design

In launching the Australian Federal Safety Commission's audio-visual on safe design, Australian Federal Safety Commissioner, Helen Marshall (FSC) noted “a safe design approach means improved useability of products, systems and facilities and results in better productivity, with work completed safely and on time. Safe design is one of the key criteria of the Scheme because of the impact it can have on the building and construction industry’s OHS outcomes.” (FSC 2007)