FORKLIFT LITERATURE REVIEW
EXECUTIVE SUMMARY

Forklift related accidents contribute a significant proportion of workplace fatalities all over the world. No more severe is this problem than in the USA, the location where the majority of forklifts are manufactured. “OHSA estimates forklifts cause about 85 fatal accidents per year, 34,000 accidents result in serious injury and 61,800 are classified as non-serious”. (Hall, 1996)

Furthermore forklift accidents occur indiscriminately across all industry sectors, however a significant fatality ‘blackspot’ exists for plant and machine operators within the Manufacturing industry (NOHSC, 1998). A high density of pedestrian workers exists within this environment, which in addition to vehicle roll-overs comprise the main accident mechanisms. Conditions like narrowed aisleways and carrying loads were found to increase the likelihood of such accidents nearly two fold. (Collins et al (a), 1999)

Certain risk factors were found to be inherent, due to the design and functional requirements of the forklift. The narrow track coupled to a variable centre of gravity makes stability a primary concern whilst operating. Cornering and the responsive steering characteristics of forklifts are two unbridled determinants of the vehicle’s stability. Toyota was found to be the only forklift manufacturer to address the issue of forklift stability, and does so with the advent of SAS technology introduced on their new 7 Series forklift. (Thomas, 1999)

Stability becomes even more of an issue when handling loads, especially when adjusting the mast whilst the forks are elevated. Both Toyota and Komatsu forklifts now have an automatic mast-levelling feature, which is an initial step towards reducing the impact of this hazard (Robertson, 1999). Further development of this feature is required so that the effects of steering actions, uneven terrain and positioning the load is represented therefore making this an even more desirable feature.

Whilst the challenge of maintaining stability for forklifts is renowned, a great concern exists due to the absence of an effective means to warn or restrict operators from handling unsafe loads or performing unsafe actions. Adaptation of attitude indicators as used in aviation to inform pilots of the aircraft’s dynamics, may be an example of a more effective means of relaying stability safety information rather than a basic load chart (Allstar Networks, 2000). This could be the first stage of technological advancement, which prevents actions from occurring that may contravene the vehicle’s safety dynamics.
Speed is a particular determinant that appears as a root causal factor in many powered vehicle accidents, with forklift trucks being no exception. Given the environment in which forklift operate, the rate of travel at which they operate has a direct bearing on the level of risk to which pedestrian workers are exposed. As pedestrian workers are involved in around 45% of accidents a need exists to control the speed of forklifts when they are in a close proximity to pedestrian workers so as to reduce the potential risk severity. (Larsson & Rechnitzer, 1994)

The means by which to coordinate speed in relation to pedestrians requires the integration of a proximity sensing system with an appropriately moderated means of automated braking. The likely model will employ laser technology to triangulate a safe passage between identified stationary and mobile objects with the central receptor on-board the forklift (Forger, 1998).

A delicate balance exists between establishing a means of braking that prevents the forklift from colliding with objects, whilst ensuring that the stability of the load being transported isn’t compromised. Possible means of meeting this requirement could see ABS technology used as means of proximity based speed moderation, as has been introduced on some Mercedes passenger vehicles (Mercedes-Benz, 1997).

Meticulous logistics planning is the essential ingredient in order for speed control and proximity sensing to be successfully introduced. This is the over-arching process that identifies all potential hazards, initiates the segregation of pedestrians from mobile plant and assigns the appropriate flow of materials. Following consideration of these factors speed zoning for mobile plant can be tailored to suit the requirement of specific areas. With around 75% of new warehouses engaging in systems integration today with the view of improving productivity, safety consideration inclusive of ITS technology is the next essential step. (Cooke, 1998)

Whilst the hazards associated with forklift operation are well known, risk controls thus far have been low level interventions, centred around operator protection and training. Therefore little has been done to curb the presence of these hazards instead a culture reliant upon education preventing the incidence of erroneous behaviour exists. This project is specifically targeted at controlling these hazards by means of engineering and administrative developments that address the key issues of stability, proximity, speed and logistics planning. This methodology ensures that an effective reduction in accidents involving forklifts can occur, which wouldn’t have occurred whilst solely relying upon the absence of operator errors.
INTRODUCTION

‘Powered industrial trucks’ is a common term referring to forklifts, container-handling trucks, reach-trucks, turret trucks and the like. Since their introduction forklifts have been an integral ingredient for materials handling across a multitude of industries. Global injury/fatality data identifies forklifts as a prominent occupational hazard that has occurred as a by-product of automation and bulk material handling. (Feare, 1999)

With the introduction of forklifts came a shift in plight of materials handling towards adopting a bulk oriented approach. This derived jointly from the need to improve productivity and to reduce the instance of workplace manual handling injuries. As a result, a niche’ market was created for specific plant and equipment to cater for such demand, but also unfortunately released a new ream of hazards to the workplace.

A lack of consideration of the interface between pedestrian workers and forklifts in the workplace has resulted in forklifts comprising many of the more serious injuries and fatalities in the workplace. These effects have been felt throughout industries ranging from manufacturing to retail environments, and require an array of engineering and administrative interventions to combat the exposed risks. These interventions should extend from the current hygiene and ergonomic focus and look towards integrating automated logistics planning, with on-board intelligent vehicle technology. (Janicak, 1999)

In Australia during the period 1989-1992, there were 52 forklift related fatalities, with most of these fatalities occurring as the result of persons being hit by falling objects (40%) (NOHSC, 1998). Recent data for Victoria indicates that this trend has only changed marginally, with around 500 claims and 2 fatalities reported annually between 1993-1997 (VWA, 1999).

The corresponding data in the USA identifies that nearly 100 forklift related fatalities are recorded annually (94 in 1995), which most often resulted from forklift rollovers (25%) (BLS, 1997&1998). Such is the profile of forklift safety in the USA, that OSHA developed standard 29 CFR* 1910.178 for powered industrial trucks (inclusive of forklifts) as a means of trying to stem the flow of incidents from forklift related operations.

At least two provinces in Canada have also identified the occupational hazard, which forklift operation poses. In Ontario 18 fatalities were recorded for the period 1990-1995 (MOL, 1999), whilst the Workers’ Compensation Board in British Columbia reported 3 fatalities in 1997 bearing great similarity to the data reported here in Victoria (WCBBC, 1998).
RESULTS

ACCIDENT MECHANISMS

The design features of forklifts is in many ways is at the heart of many forklift related accidents. The intersection between the shifting centre of gravity and the narrow track of the forklift, combined with the requirement to handle loads at height can have detrimental effects on the vehicle’s stability. Much of the problem lies is in the success of the operator maintaining the forklift’s centre of gravity within the triangle formed by the three suspension points. “If the centre of gravity goes out of this area by lifting a load that is too heavy, or by carrying a load too high and tilted forward, the forklift will tip over”. (AMIC, 1999)

Shared pathways and close interaction between forklifts and pedestrian workers was seen to contribute around 35% of the total accidents occurring in a motor vehicle manufacturing plant in the USA. Whilst 923 of 926 of these accidents resulted only in an injury, 41% of these required time off work, at an average of 61 days per incident. Thus far the majority of interventions have revolved around the training of forklift operators and promoting segregation of pedestrian and motorised traffic. (Collins et al (a), 1999)

The following table clearly identifies the mechanisms that resulted in 52 fatalities to Australian workers during the period 1989-1992. It is noteworthy that both of rollovers and pedestrian contact figure prominently in this data.

Table 1
(NOHSC, 1998)

<table>
<thead>
<tr>
<th>MECHANISMS OF FORKLIFT RELATED FATALITIES IN AUSTRALIA 1989-1992</th>
</tr>
</thead>
<tbody>
<tr>
<td>INCIDENT TYPE</td>
</tr>
<tr>
<td>Load falling onto the operator or another worker</td>
</tr>
<tr>
<td>Roll-over of the forklift</td>
</tr>
<tr>
<td>A worker being hit by the forklift</td>
</tr>
<tr>
<td>A working falling from the raised forks</td>
</tr>
<tr>
<td>Bystanders</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
</tr>
</tbody>
</table>
The National Traumatic Occupational Fatalities (NTOF) Surveillance System in the USA shows that 1,021 workers died as a result of forklift related incidents during the period 1980-1994. The causal factors for these fatalities can be seen on table 2. It is also interesting to note that, “the greatest proportion of the fatalities (37%) occurred to workers in Manufacturing, whilst the highest forklift-related fatality rate per ten million workers occurred among transport operatives (34%).” (Collins et al (b), 1999)

Table 2
(NIOSH 2000-112a, 1999)

### MECHANISMS OF FORLIFT RELATED FATALITIES IN THE USA, 1980-1994

<table>
<thead>
<tr>
<th>INCIDENT TYPE</th>
<th>NUMBER</th>
<th>PERCENTAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forklift roll-over</td>
<td>225</td>
<td>22%</td>
</tr>
<tr>
<td>Pedestrian worker struck by forklift</td>
<td>204</td>
<td>20%</td>
</tr>
<tr>
<td>Victim crushed by forklift</td>
<td>163</td>
<td>16%</td>
</tr>
<tr>
<td>Fall from raised forks</td>
<td>92</td>
<td>9%</td>
</tr>
<tr>
<td>Others</td>
<td>337</td>
<td>(33%)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1,021</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

In addition to the possible shortcomings in product design that contribute to forklift roll-overs, are a litany of behavioural induced systems breakdowns. The mismatching of factory logistics and work processes can result in increased risks of pedestrian’s being struck by forklifts. (Collins et al (c), 1999)

The practice of using the forklift to gain access to height is one that requires stringent supervision and is only permissible when in a fully equipped working platform (MOL, 1999). A hazard often originates with actions like riding with the material or hitching a ride standing on the tines of the forklift. This practice doesn’t only show a disregard for safe work practices of both only the operator and worker, but is indicative of a lack of safety management at supervisory and managerial level.

The causal factors of loads which fall whilst being handled isn’t restricted to lack of driving training. In fact verification of the required action with specific load masses is also often under-represented on the load chart placard on the forklift, therefore deeming many inadequate. Assuming the load chart is still attached and legible, there is often a lack of operator instruction regarding the impact on forklift stability with the requirement to manoeuvre the load at height.

The list of contributing factors to the instance of falling loads extends above and beyond the lack of information provided in many load charts. The practice of not properly securing loads and working under a raised load severely magnifies the scope of the hazard. Additionally inappropriate/modified forklift attachments and lifting loads without setting the tines to the appropriate width of the load are also causal factors to the instance of falling objects. (Scott, 1996)
STABILITY CONTROL SYSTEMS

As highlighted by international data the primary mechanism of forklift related accidents are vehicle rollovers. This is largely the product of forklifts weight distribution forming a ‘stability triangle’ of sorts, which is further destabilised by its high centre of gravity and narrow wheel track. (Thomas, 2000)

As has been the case previously the road safety paradigm has been at the forefront of development of safety innovations. Stability control systems are already widely used for motor cars in Europe and are gaining rapid momentum in the USA. Whilst the systems do vary slightly, the ingredients are much the same. Each of the systems adds three sensors to each wheel where the antilock braking system is applied.

The first of these sensors detects steering wheel angle whilst the second sensor detects vehicle spin (yaw), and the third monitors turning force. When the system detects variance from pre-programmed vehicle behaviour patterns it briefly applies the brakes to one wheel, therefore preventing the vehicle ‘fishtailing’ and eventual loss of control. (Hyde, 2000)

In specific cases The Ford Motor Company in the USA is in the process of incorporating such systems on all SUV’s (Sports Utility Vehicles). The introduction of the ‘Advancetrac system’ to SUV’s was deemed necessary as a means of improving vehicle stability, due to the propensity for rollovers. This exposure group is magnified due to the doom market for SUV’s, which are expected to account for around 20% of total industry sales in the USA. (Driving Sense, 2000)

General Motors offers a similar system to consumers under the guise of a system referred to as ‘StabiTrak’. This system has been fitted to certain models under the Buick and Cadillac banner, with already more than 400,000 units finding there way on to the road since 1997. Where StabiTrac differs lies within the front wheel drive configuration of the Cadillac Seville. This in essence total vehicle stability can be influenced by use only of the front brakes. (Cadillac Eldorado, 1998)

The Mercedes M Series and BMW X5 typifies European interest in automatic stability control technology. Mercedes refers to its system as the Electronic Stability Program (ESP), which again monitors the vehicle’s response to driver steering and braking inputs. If over or understeer is detected individual front or rear brakes are applied and/or reduced excess power so as to maintain control of the vehicle. (Mercedes-Benz, 2000)

The inter-relationship between passenger vehicles and forklifts is somewhat under developed. This relationship is blurred to a degree by the ideology perceiving the base configuration of a forklift as being similar to that of a passenger vehicle, without considering its inherent hazards (Feare, 1999). Effective risk reduction for forklifts in industrial environments may benefit from the extraction and application of established road safety ideology. Aided computer vision and automated logistic planning are likely to be essential ingredients for such development to occur. (Garibotto et al, 1998)
Findings of a previous forklift related study conducted by Larsson and Rechnitzer (1994), states that many forklift related hazards stem from not treating forklift trucks as ‘vehicles’ requiring systematic traffic management in the working environment. When using this definition as a point of origin a systematic traffic management plan for forklift use in the workplace can result.

From this foundation many aspects of the road safety model can be incorporated and applied. Warehouses can be designed, mindful of factors like maximising traffic and material flow whilst moderating the forklift truck and pedestrian worker interface. Additional safety features can also be added to the forklift under the guise of ITS (Intelligent Transport Systems) innovations, much in the manner suggested by Stuckey (1996).

Toyota is the first forklift manufacturer to apply these design principles, as is seen with the introduction of their System of Active Stability (SAS) to the new 7-Series forklift. This system is described as an electro-hydraulic control system designed to increase operator safety by reducing the risk of roll-over. The application of such technology to forklifts, is an example of gains that can be made when recognising forklifts as vehicle’s, that have similar issues and design solutions to passenger vehicles.

The SAS technology is designed to maximise latitudinal and longitudinal stability by regulating the active control rear stabiliser and active mast functions, as opposed to the independent application of ABS technology commonly used on passenger vehicles. Four sensors are used to monitor the height of the fork, the load on the fork, the speed and yaw of the forklift. This data is fed into an on-board computer that drives adjustment to the rear stabiliser and mast controller. (Thomas, 1999)

The Active Rear Stabiliser is a hydraulic cylinder subject to computer control, which closes the flow of hydraulic fluid locking the rear axel. This occurs in response to detection of instability, when lateral forces pose the risk of potential roll-over. In conjunction to improved operator safety, this system has the added potential benefit of improved productivity by safety guarding against shifting loads. (LMDR, 1999)

The system also incorporates a system referred to as Active Mast Controller. This function moderates the speed at which and angle of the mast, ensuring that the mast moves in a smooth fashion. This function also limits the mast from angling more that 1-2 degrees off level which guards against forward tip-overs. In complement to the active mast function controller is the automatic fork-levelling device. This allows the operator to quickly re-level the forks up to the height of 196cm, thereby assisting with the precision of the stacking of loads. (Thomas, 1999)

The end product of SAS technology is a stabilisation of the load and vehicle by ensuring the centre of gravity can shift safely whilst maintaining solid contact with the ground. This testimony is compounded by demonstrations of SAS equipped 7-Series Toyota forklifts, performing 180 degree power slides at full speed without roll-over. (Thomas, 1999)
LOAD CHARTS

Another factor having influence over the stability of forklifts is the manner in which loads are handled. Much of the information operators require in order to determine whether the load can be safely handled by the forklift, is contained on the vehicles load chart. However reliance on load charts to portray all the necessary information is fraught with risks, as that they often don’t contain enough information for the variety of functions that the operator is required to perform whilst handling the load.

The inadequacy of load charts doesn’t end with the lack of information they contain, but also extends to the manner in which the information it does contain is portrayed. Crane operators who perform materials handling functions in a similar manner to forklifts have reported a high instance of operators unable to decipher their machines load charts. Actual statistics given for crane operators in the USA found that less than 10% of operators could correctly interpret load charts. This data may in fact be magnified due to the instance of unlicensed forklift operators throughout industry. (Crane Institute of America, 2000)

Whilst there are around 250,000 crane operators of in excess of 200,000 cranes in the USA, a figure significantly lower than for that of forklifts, some distinct patterns are determinable. Mobile cranes the variety of crane with has the closest semblance to forklifts were involved in 115 accidents over the three-year period of 1997-1999. Interestingly enough 25% of these accidents were of a direct result of the load capacity having being exceeded. This may indicate that the lack of understanding of load chart information is actually resulting in a direct steam of crane related accidents. (Yow, 2000)

Visual inspection of the level of information conveyed by different forklift manufacturers’ load charts varies considerably. Some represent merely the capacity of the forklift in ideal conditions, whereas others endeavour to convey information that reflects how the lift capacity is reduced by raising the forks and/or shifting the load in relation to the centre of gravity. Documentation of stability tests conducted on the effects of load height and position appear could be more effectively conveyed by adopting a user-friendly tool.

Such an item could take the form similar to that used by 4WD vehicles and in aviation and maritime environments, which by aid of compass-like object shows the vehicle’s angle in relation to the terrain it is operating on. This technology is referred to as attitude indicators in aviation and act as a substitute for the earth’s horizon, while providing information in regards to climb, dive and bank angles. The attitude indicator plays a vital role in overcoming our inaccurate sensory perception in certain conditions, therefore safeguarding against human error. (Allstar Network, 2000)
PROXIMITY SENSORS

Whilst contact with pedestrian workers is one of the main accident mechanisms involving forklifts that results in injury or even death, collisions with other objects is also of concern. Due to the often, restrictive layout in which forklifts operate and the requirement for them to interact extremely closely with trucks and delivery vehicles, a method of safe guarding this interface is required.

Proximity sensing is such a system. Whilst there are a couple of ways in which to apply this technology, the principle remains constant. The system basically detects the distance between the vehicle and other objects. In order to maintain a pre-programmed safe distance and to avoid collisions systems moderates speed by retarding acceleration or by application of the brakes.

This technology has been applied and customised by passenger vehicle manufacturers, namely Mercedes-Benz, who has interlaced a laser proximity sensing system with cruise control technology. The end product of this innovation is automated variance of cruise speed relative to other vehicles. This system is active for speeds between 35-150km/h, and can monitor vehicles up to 120m ahead by the aid of the bumper mounted laser and powerful internal microcomputer.

( Mercedes-Benz, 1997)

When considering the application of proximity control technology, the option of encasing it within an entire systems automation envelope is often luring. An example of this is technology is already available via ‘Hyster’, who manufacture an automated turret truck. Complete automation takes the idea of proximity control to the next level and removes the ‘people factor’ from the process involvement phase, thus eliminating the hazard of forklift and pedestrian worker contact.

The flip side of automation lies in the cost of the system and the redundancy of workers. Initial cost estimates for a fully equipped automatic guided vehicle system incorporating one forklift and warehouse adaptation is in the region of $100-200k US. Where the real impact is likely to be felt as a result of automation, is that many of the 1.5m forklift operators in the USA would become obsolete even if only a part of the 1m forklifts were automated (Feare, 1999).

It is important however, to not lose sight of the technological advancement of automation, as much of it can still be applied. The means by which AGV’s navigate is of great relevance to proximity control. Wire guidance, three variations of optical non-wire guidance, laser guidance and inertial guidance are all such methods of navigation, with laser guidance already forming the basis for several developing proximity control systems.

Wire guidance is the most common method of AGV navigation at present, and is reliant on an in-floor guidance antenna containing two coils on each side of the antenna. Voltage differences between the two coils initiate a steering signal that controls the movement of the steering motor and the subsequent movement of the vehicle. (AGV, 2000)
The first two methods of the optical guidance are reliant upon a magnetic or chemical path on the floor, which the AGV can follow. “An optical sensors on the vehicle constantly seeks the path, ensuring that the track is followed”. If the vehicle veers from the path, steering adjustments and course correction takes place. The last of the optical guidance systems employs a floor-mounted checkerboard pattern of light and dark squares to guide the vehicle. “Using a distance encoder in the wheels and checkerboard squares as reference points, an on-board computer determines the actual position of the vehicle against the expected position, making corrections as needed”. (Forger, 1998)

Laser guidance systems don’t rely upon floor-based reference points, rather an on-board laser searches for targets positioned on the walls of the structure. “Using two or three targets, the on-board computer triangulates to determine the AGV’s actual position and compares it to the expected position at that point in its route, making adjustments as required”. Finally inertial guidance systems incorporate on-board navigational gyroscope and encoded electronic signals to compare actual and predicted locations. “Navigation computers that make the computations can be either on-board or at a central control room that communicates with the AGV by radio frequency”. (Forger, 1998)

In each of the above systems, vehicle guidance is reliant on successful mapping of facility coordinates, so as to determine the most appropriate pathway. Direct extraction of this technology highlights the need for careful hazard identification, which transpires into a blue print for warehouse and facility design necessary for successful proximity implementation.

Warehouse systems integration is one of the most rapid growth areas in the service sector of the warehouse and logistic industry today. The Gartner Research Group notes that systems integration using cutting edge software technology is involved in around 75% of present day warehouse designs. Three years ago this figure was closer to around 25%. With systems coordinators managing the interface between various warehouse components with the aim of improving productivity, consideration of ITS principles to vehicle movement is the next essential step. (Cooke, 1998)

Improved OHS has been one of the lesser motivators of warehouse modification and development for some time. This trend has changed somewhat with the recognition of the cost of worker’s compensation and disability claims that arise from poorly designed warehouses. Dock levellers with trailer restraints, safety belts on forklifts and the introduction of the new standard for powered industrial trucks has been seen as the catalyst for improved safety consideration in the warehouse environments. (Salkin, 2000)

The issue of specifically applying support technology for improved transport and logistics within warehouses and freight terminals is only now becoming apparent. The application of ITS (intelligent transport systems) technology is seen as a possible method of integrating the shared goals of improving safety and productivity. It is now conceivable that for management of warehouse and freight terminals, ITS involvement is imperative for effective systems management. (Hughes, 1999)
ROLL-OVER AND RESTRAINT

Vehicle roll-over is a causal factor that is considered to contribute to around one quarter of fatalities involving forklifts. Interventions by which to control this hazard was found to draw on both agricultural safety and road safety knowledge, and apply operator restraint systems (seat belts) and falling objects protective structure (FOPS)/roll over protection structures (ROPS).

ROPS, is a cab or frame that provides a safe environment for the operator in the event of a roll over. This device was initially designed for application in agricultural environments where roll-overs of tractor’s accounts for nearly one third of farm related deaths. Research in the USA found that almost half of the tractors in Illinois didn’t have a roll-over protective structure fitted. (National Safety Council, 2000)

Structural integrity of the ROPS device is essential due to the large mass of the vehicle that it must sustain in the event of a rollover. Therefore adherence to specific quality standards is essential so as to ensure operator safety, which in the UK mandates meeting the requirement of ISO 3471. In the UK roll-over protection for plant and construction equipment was required from 5th December 1998 under the ‘PUWER 2’ 1998 Health and Safety Regulation. (ROPS Ltd, 2000)

Whilst OHSA in the USA and the Health and Safety Regulators in the UK both endorse the manufacture and retro-fitting of ROPS devices, neither of them mandate the fitting of seat belts. Seat belt installation has been universally applied by the road safety paradigm as a means safeguarding the operator against contact with harmful objects. Application of seat belts to mobile plant and equipment would work in synergism to the ROPS device. This would ensure that the operator doesn’t fall into the path of the ROPS structure or under the machine and get crushed. In Australia it is predicted that when ROPS and operator restraints and used in unisom 20% of fatalities could be prevented. (NOHSC, 1998)

Extending the ideology of ROPS technology to industrial environments gave birth to FOPS (Falling Object Protection Structure). These are fitted to all forklifts to provide a means of operator protection in the event of a falling load or being crushed under an over turning forklift. Similar can be said of forklift regulations that was the case for agricultural equipment which basically means that seat belts aren’t prescribed to be fitted to all forklifts. Even forklift regulations introduced as recently as 1999 in the USA adopt this approach. Requirement only states that removed restraints are to be refitted and where they are fitted requiring them to be worn. (Lear-Olimpi, 1999)

It is apparent that further steps are required to curb the hazard associated with forklift roll-overs, especially in light of the significant reduction in fatalities that can be avoided by installation of existing technology. Whilst the means of reducing the instance of this hazard is available in the guise of ROPS, FOPS and seat belts, true reduction in fatalities is likely to result when clearer directives are prescribed by regulators. In the absence of such a directive alternative means are required to protect against the hazard of roll-over. These could include engineering advancement in the way of stability controlling or warning devices in conjunction with total protective cages that prevent the operator from being crushed.

09/08/11
MUARC OHS GROUP
FORKLIFT SAFETY PROJECT

13
CURRENT FORKLIFT DEVELOPMENT

The majority of research for forklifts to date has been directed towards improving efficiency and technical capabilities. Subsequent development in this area has seen the introduction of narrow aisle applications, improved engine efficiency and maintenance access. More recently research has been conducted to investigate safety measures like ROPS and seat belts in order assess their effectiveness in terms of occupant protection. (Jenkins, 1999)

Operator training is another area where a degree attention has been focussed, and largely as a result of regulatory pressures. Moderating operator behavioural patterns has in many ways been seen as a method of administrative control, thought to be a relative inexpensive means of reducing the incidence of forklift related workplace accidents. This approach is also aimed improving the sense of ownership for forklift safety amongst employer groups. (Health and Safety Executive, 2000)

From the manufacturers perspective ergonomic considerations has also been a part of the development process. Ergonomic consideration in the main is aimed at reducing the instance of whole body vibration and static muscle loads. This tangible quality adds credence to claims of improved productivity and as a result pays for its own development costs.

Mitsubishi’s new range of cushion tyred forklifts with lift capacities ranging from 1,360-2,721kg has promoted the development of a range of internal combustion engines and its ergonomically designed cabin. The new seat is designed to improve lumbar and thigh support in normal operation whilst to also provide arm support when reversing. Furthermore the synthetic rubber engine mounts effectively dampen engine vibration, with the overall aim to reduce operator fatigue. (Robertson, 2000)

Toyota’s who has manufactured over 1 million forklifts worldwide over the past 40 years has made some significant advancement with the new 7-Series forklift. This model encompasses a cushion tyred range with internal combustion engines with 1,814-2,948kg capacities. A pneumatic tyre range of forklifts is also offered with internal combustion engines and lift capacities ranging from 1,360-4,989kg. (Robertson, 2000)

However the real advancement has occurred as a result of technological advancement in the form of a system known as SAS (System of Active Stability). This system actively monitors and adjusts the rear axle so as to prevent it from tipping over. The active mast control function moderates mast and fork function, so as to ensure load stability. (Thomas, 1999)

Ergonomic development has also been a focus of Toyota. Instrument panels and control levers have been located so as to maximise operator visibility, with an optional EZ foot pedal allowing for hands free direction control. The hydrostatic power steering system allows for a 100% stationary turn ratio with minimal operator effort. (Robertson, 2000)
Hyser’s which has been involved in materials handling for around 70 years sells about 90% of their products to the European and African markets. They have products that can handle up to 52 tonnes, within their 63 electric powered counterbalanced models and 51 internal combustion forklifts. The H70-120XM range of pneumatic tyre lift trucks is fully equipped with a new cooling system, specially designed to handle heavy loads. (Hyster, 2000)

In addition to this they have developed a new ComfortCab, which has soft arm rests and hip restraints complete with a retractable seat belt, and consideration has gone into ergonomically locating the hydraulic levers. “A state of the art microprocessor controls gauges, hour meter, engine automatic shutdown (optional) and operator lockout keypad” (Robertson, 1999)

Drexel Industries has supplied military and industry markets for nearly 40 years and has been at the forefront of innovation since the development of the ‘Swing mast’ line in 1968. Recent development has seen the introduction of the EX series forklift, which is designed to operate in hazardous environments, due to specific design criterion deeming it explosion proof. (Drexel, 2000)

Improved performance, better ergonomic consideration closely integrated within a restyling regime, are the features of Caterpilla’s new three-wheeled electric counterbalanced lift trucks. This 1,360-1,815kg range also provides for operator conveniences like a low entry step and large grab handle. Similarly Daewoo’s new 2,000-3,000kg capacity range of lift trucks has also directed a degree of attention towards operator comfort, with the counterbalanced crankshaft design reducing engine vibration. (Robertson, 1999)

Komatsu has produced a wide range of industrial vehicles integrated amidst various transport system synergies since its inception in 1945. The introduction of an automated guided forklift truck system is in many ways a beacon for Komatsu’s research and development driven progress. Other recent design innovations have heralded improved steering performance within its Komatsu Advanced Power Steering System (KAPS) technology. An automatic fork-levelling device has also allowed the operator to more easily parallel the tines, and is further complemented by the soft landing mast, that reduces noise levels and the potential damage to transported materials.

Directional control has also been overhauled by the use of an electric forward/reverse shift, which allows for an almost instantaneous change of direction. Added to this is the introduction of double coned synchromesh gears, which ensure that gear changes are smooth and load stability isn’t compromised. Ergonomic considerations are also features of Komatsu’s AX, BX and CX Series lift trucks. This has resulted in the inclusion of large open step and grab rail, which improved operator access and egress. The LPG cylinder counterweight has the user-friendly swing down bracket that reduces the manual handling risks associated with changing cylinders. (Komatsu, 2000)
Linde global operation ensures that it is the largest manufacturer of materials handling equipment. Its 18 models of forklifts with load capacities ranging from 1,000-52,000kg are marketed under 3 brand names (Linde, Still and Fiat-Om) which are in direct competition. Linde, synonymous with hydrostatic transmissions 1958, has applied this technology to the steering systems of its products. Hydrostatic steering virtually ensures its product will require less maintenance, lower running costs and subsequent result in higher productivity.

Other design features are the torsion support system that increases mast stability when carrying swinging loads by as much as 30%. Electrically powered models benefit from a multi-function joystick control referred to as Linde Load Control (LLC) which allows for smooth fingertip control of all hydraulic functions. The LLC was factored into a total ergonomic upgrade of the operator’s cabin. This provided for a weight and position adjustable seat, complete with lumbar support aimed at improved operator comfort. (Linde, 2000)

Clark’s Material Handling Company new M-Series forklifts are of 3, cushion tyre configuration with lift capacities 1,500-2,000kg. The short wheelbase allows for maximum manoeuvrability of heavy loads in confined areas. A two pedal inch brake system allows for delicate materials handling requirements, whilst the safety seat and seat belt is all a part of the operator safety restraint system. Rubber isolation of the cabin in designed for reduced vibration whilst in frame steps further complement operator comfort.

Improved operator comfort is also a feature Raymond’s counterbalanced forklifts. Here forearm rest pads, a low-pressure brake pedal, a low step height and angled floor is aimed at reducing operator fatigue. Cabin design has also been more closely matched with the operator, due to the inclusion of a simultaneous function control handle, governing direction and speed of travel, lift, lower, tilt, side-shift and the horn. (Robertson, 1999)

Nissan has been involved in the manufacturing of forklifts since 1957 and today manufactures 35,000 units annually exporting to 85 countries. Nissan’s new electric three-wheeled forklift utilises a dual front wheel drive motor system and allows for specific performance parameters to be easily modified. An adjustable tilt steering wheel and power steering which caters for ease of operation is mirrored by a full suspension seat and individual float system on engine powered trucks. Nissan also now offers an enclosed see-through cabin for use in cold environments. This technology has the dual benefit of improved operator protection in the event of roll-overs or falling objects.

Improved air quality in forklift operational areas, has seen the efficiency of Nissan’s internal combustion engine range receive the benefit of company wide research and development. A 3-way catalytic system for the LPG models has improved fuel economy by 20% and emissions by 90%. Whilst the diesel engine can already meet stage 2 emission requirements and are already considered amongst the most economical forklift engines on the market. (Nissan, 1999)
The introduction of new legislation for Powered Industrial Trucks (Standards 29 CFR-1910.178) in the USA appears to have acted as the catalyst for legislative review for forklifts, with several other regulators in other parts of the globe echoing the stance of OHSA. “On March 1st 1999 the new rule on powered industrial truck operator training became effective”. This rule mandates far greater employer responsibility especially with regard to operator training and retraining as a result of closer monitoring of operator performance of various types of industrial trucks.

“Employers were given until December 1st 1999 to complete training and evaluation of their operator’s performance for those employees employed before that date”. Training and evaluation of employees who commenced after that date must occur prior to them operating the forklift. The introduction of this new legislation for industrial vehicles was 10 years the USA was 10 years in the pipeline, and originating with the Industrial Truck Association (ITA) petitioning OSHA for a more prescriptive legislation so as to combat forklift accidents in the workplace. (Feare, 1999)

Flexibility is an inherent characteristic of these regulations due to the recognition of the variances that exist between workplaces. The training regimen that results revolves around three factors: formal instruction, practical training and an evaluation of the operator’s performance, which must address 22 topics if applicable. Re-evaluation of the operator’s performance must occur at least every three years, with more frequent training if required. (Estabilio, 1999)

Whilst the regulations are focussed towards forklifts, pallet jacks and motorised hand trucks they also apply to people who occasionally use such machinery to unload cargo. Truck drivers are those among this group and are reputably involved in around 6.7% of the annual powered-truck injuries in the USA. The truck drivers employer bears the responsibility to train their driver, even if they only operate forklifts, or the like, at other company premises whilst delivering or receiving goods. (Johnson, 1998)

OSHA estimates that after its regulations are effective as of December 1999 in the USA, it would correspond to one life saved per month, or around 11 over the course of a year. Further impact of the regulation is likely to materialise in the form of a 10% reduction in injury claims in the USA (Feare, 1999). NIOSH backed research noted that improved performance of up to 61% can result from well-planned training programs. It was observed that fewer errors were made which correlates into, less damaged products, increased productivity and gives credence to the claims made by OSHA, of reduced injuries and fatalities associated with the introduction of the new regulation. (Estabilio, 1999)
Powered lift trucks are widely used throughout numerous industries in Canada, requiring all three Ministry Sectors (Mining, Construction and Industrial Establishments) to have provisions for forklift trucks. “The largest number of companies are covered by the Regulation for Industrial Establishments, Regulation 851”. (MOL, 1999)

Regulation 851 and the OHS Act both have relevant clauses that govern the operation of forklift trucks. Specific clauses are directed towards the employer’s duty of care for their employees. These chiefly stipulate the requirement to supply equipment that is in good condition, within the overarching umbrella of protecting all workers. Other relevant clauses for forklift operation are tailored towards ensuring that the operators are appropriately trained and receive adequate supervision. (MOL, 2000)

The specificity for operator competence requirements differs between the Act and regulation 851. “The OHS Act places the obligation on an employer to provide information instruction and supervision to a worker to protect the health and safety of the worker. Regulation 851 is more specific and states that a lifting device is only to be operated by a competent person”. To be considered competent the worker needs to be trained and have experience in order to be qualified. (MOL, 1999)

For an effective systems approach that will satisfy relevant regulations the following factors should be addressed:

- Hazard Identification
- Operator and Proximal Worker Training
- Provide Effective Supervision
- Documented Operating Procedures (JSA)
- Maintenance and Repair Procedures
- Ensure Facility Design Compatibility

(MOL, 2000)

In the UK many instances of lift truck accidents are associated with a lack of suitable operator training. The Health and Safety at Work Act 1974, stipulates that employers are responsible for ensuring the safety of their employees. Training is one of the many requirements addressed by various regulations. The Provision and Use of Work Equipment Regulations 1998 extends the duty of care of the employer beyond just operator training. This regulation not only stipulates that the appropriate supervision of operations be apparent, but those who partake in the supervision must has received suitable training. (HSE (a), 2000)

To more specifically focus on OHS issues that surround the usage of forklifts, a Code of Practice and Supplementary Guidance is prescribed by ‘Rider operated lift trucks – operator training’ ISBN 0717624552. “This publication advises employers on training for lift truck operators”. Other guidance notes have been introduced to deal with identified hazards that arise as a result of forklift operation. These are intended to complement both general and specific regulatory publications (HSE (a), 2000).
Working at height where access is gained via a temporary work platform is one such hazard, and it is thought that around 10% of total forklift related fatalities are attributed to this hazard. Guidance Note PM 28 for Working Platforms on Fork-lift Trucks was introduced so as to more effectively mandate the design, selection and use of suitable working platforms. The aim of this legislation was to identify how mobile industrial trucks with vertical masts and those with telescopic booms can safely use working platforms in a safe manner. (HSE (b), 2000)

The Lifting Operations and Lifting Equipment Regulation 1998 is an example of a regulation that fairly specifically targets forklift safety. “This regulation requires employers to ensure that all lifting operations are properly planned by a competent person, appropriately supervised and carried out in a safe manner. Another more general regulation that effects the downstream safety of forklift operations is the 1992 Regulation, ‘The Supply of Machinery (Safety). This places ownership on those who supply machinery and safety components, ensuring that essential safety requirements are met before the machine or component is purchased. (HSE (b), 2000)

Closer to home the VWA (Victorian WorkCover Authority), this projects funding body and industry stakeholder, has a keen interest in raising the bar of forklift safety within the confines of a self regulatory paradigm. The design, manufacturing, marking and testing requirements for ‘powered industrial trucks’ are centrally governed by the Australian Standards, number 2359 and its 12 subsections. Each of the parts of AS 2359 address issues spanning from general requirements to actual stability tests, but still rely upon additional governance at the workplace level stipulated by jurisdictional acts and regulations. (AS 2359.1-1995)

In Victoria the basic framework for all the parameters contributing to workplace safety is supplied by the Occupational Health and Safety Act 1985. Section 21, 2b, of the Act, has specific reference to the duty of care of employers who use ‘powered industrial trucks’ (inclusive of forklifts) in their workplace. More specifically it requires employers to make arrangements ensuring that handling, storage and transport of plant and substances occurs in the absence of risk as far as practicable. (OHS Act, 1985)

Further provisions are made within section 59 of the OHS Act 1985 to introduce additional/complementary regulations to more specifically state how to protect people at work. Occupational Health and Safety (Plant) Regulations 1995, S.R No. 81/1995, is a specific example of this. This legislation was introduced with the purpose of protecting against risks to health or safety, arising from plant and systems of work related with plant in the workplace. (OHS Plant, 1995)

Regulation 711, of the Plant Regulations 1995 deals employer’s duties in relation to general requirements for powered mobile plant. A close alliance exists between each of the subsections of this regulation and the causal factors of mobile industrial plant/forklift accidents. This occurrence is no coincidence, as the framework of the Plant Regulations is based around the process of hazard identification, risk assessment and risk control for all plant and equipment in the workplace. (OHS Plant, 1995)
Sections 1 and 2 of regulation 711 require the employer to eliminate as far as practicable, the likelihood of the powered mobile plant overturning, having falling objects strike the operator, or the operator being ejected from the plant. Where these risk are apparent the employer should install an array of operator protective devices so as to control the identified hazard (OHS Plant, 1995). Such interventions usually take the form of ROPS or FOPS and a type of operator restraint system, all of which are common addition to most forklifts.

Section 3 of regulation 711 requires the employer to eliminate the risk of powered industrial plant colliding with pedestrians or other plant. This translates to the need for appropriately organised logistics that promotes segregation of the operation of powered mobile plant from pedestrian workers. Due to the limitations of practicability, which identifies that the redesigning of existing structures may not always be feasible another option is required (OHS Plant, 1995). Proximity sensing is such an alternative. This could be effectively applied to safe guard all personnel and equipment when total segregation of work areas isn’t achievable.

Section 4 of regulation 711 requires the employer to install a warning device to mobile plant where the numerous operations and work groups are occurring in a given area (OHS Plant, 1995). Flashing visual warning devices is the most common means of alerting as to the presence of mobile plant. This method is favoured to audible beepers due to the nuisance factor that would result in the event high-density operation of mobile plant in locations like markets.

Section 5 of regulation 711 requires the employer to ensure that only the operator rides on the powered mobile plant, unless there is provision to transport another person at the same level of protection as the operator (OHS Plant, 1995). This section of regulation 711 addresses the issue of, the employer ensuring that all company operations are appropriately supervised, within an all-incumbent safety culture.

The intended purpose of section 21 (2) of the OHS Act 1985 and regulation 711 of the Plant Regulations 1995, is without doubt to minimise the risk of injury to employees via exposure to mobile industrial plant. The term ‘practicable’ refers to the state of knowledge of and the availability of suitable controls to manage a hazard. This term also recognises that cost restraints may also limit the application of certain interventions (OHS Act, 1985).

Given the lack of innovation in the area of stability, speed and proximity controls for forklifts that often operate in inefficient logistic environments, a considerable variance in risk severity results by the inclusion of the term ‘practicable’. Never before has there been a more universal requirement for development in the way of a ‘smart forklift’, especially in light of the re-introduction of industrial manslaughter, enforceable by common law, in the state of Victoria.
“Systems development methods or software methodologies have evolved considerably over the past few years, with the development tended to fall into two main areas, software engineering and human computer interaction (HCI).” The variety of software engineering assumed the form of structured analysis and semantic modelling. (Wesson et al, 1995)

Where these two techniques vary, is that structured analysis focuses on analysing the dataflow between modules, whereas semantic modelling analyses the structure of the data in the system, in order to create a conceptual model. The merger of these two approaches gave birth to modern structured analysis, which has subsequently been replaced by Object Oriented Analysis and Design (OOAD). The advantage of this technique is that it holistically encapsulates data and processes into object form. (Yourdon, 1989 &1994)

In the region of human computer interaction (HCI), various means of task analysis has been used to model the cognitive nature of tasks. “Analysis of task object modelling is an example of such a method that combines task analysis with object modelling in an integrated life cycle.” This object modelling method uses the Jackson System Development (JSD) for user interface design. “JSD is a method for specifying and implementing computer systems, whose subject matter has a strong time dimension, eg real-time, data processing and simulation systems, and consists of three major phases: modelling, network and implementation”. (Wesson et al, 1995)

Static modelling is a valuable tool that enables demonstration/rehearsal of various product prototypes within 3D visualised environments. “This imagery can explore all elements of a development; both internal and external elements can be explored with either a single angle viewpoint or multiple viewpoints”. Once a design has been transferred into a 3D environment, manipulation of the viewpoint can be achieved to formulate new images allowing complete visualisation of any given project. The accepted formats for 3D model visualisation generally include such files as dxf, dwg and eps which can be transferred from the likes of Autocad, Arc+ and Autosketch, with outputs being jpg, bmp, Quicktime and tif. (Ripe Designs, 2000)

The complexity of the available static modelling programs isn’t restricted to 3D visualisation. Process modelling and simulation is a more basic program, which is an ideal method for businesses to reduce the risks associated with introducing change. Effective modelling will reduce the chance of bottlenecks occurring in the production process, and will increase the certainty of proposed changes bringing improved productivity. This occurs by the use of graphics and natural language, which presents a hierarchical system of interconnected activities. The useability lies in relatively small amount of information presented in a given area, and that the methodology contains only two elements, boxes and arrows. (Business Improvement Software, 2000)
At the other end of the complexity-scale, are software packages that enable you to perform component-based and object-oriented analysis, design, and implementation, such as System Architect 2001. Such programs use the new standard notation for object-oriented modelling, Unified Modelling Language (UML). “Furthermore the component modelling capabilities allows modelling and documentation of the design process, as a result of the capturing of business requirements”. (Popkin Software, 2000)

Various types of 3D CAD software exists, with some giving you the power to see your design, create and rearrange constantly in live 3D. Certain software packages like DesignWorkshop Professional, actually allow the creation of furnishings, terrain, and architectural context, from a hand-drawn sketches to professional quality presentations with the most accurate natural lighting simulation. The advantages of this type of software packages is that they are fast, easy, and provide a powerful live-3D modelling interface. These features are especially useful walk-through simulation for architects and interior designers, whilst also being compatible with available software packages like autocad. (Artifice, 1997-2000)

CYCAS is another software package that can be applied to typical CAD functions, which offers special elements and techniques for architectural design. “Elements, such as walls, windows, doors and units are designed to help develop 2D drawings and at the same time build up a 3D model of your design which can be altered in several projections”. (Frese, 2000)

Advancements in software for architectural and engineering applications often stem from the AutoCAD program. A recent piping design project was completed in about 1000 hours with a three-dimensional computer program called Pro-Series. “The advent of this software represented a saving of at least 25% of the time that would have been required with generic AutoCAD.” (Franklin, 2000)

The advantage of this program lies within the ability of designers being able to model the entire plant once, whereas the generic AutoCAD program would have meant that most of the plant would have had to be repeatedly re-drawn. A considerable amount of time can be saved by specific software packages like Pro-Series, which allows for numerous orthographic and isometric drawings to be generated directly from the original model. “This enables orthographic and isometric views to be produced, from drawings off 3D models would have been virtually impossible to create with AutoCAD in a 2D model, such as an isometric view.” (Franklin, 2000)

The demand for computer based 3 dimensional design will endure the continued development, innovation and availability of a variety of software packages similar to the ones mentioned previously. The application of advanced logic systems (ALS) that produce fully interactive 3D warehouses, complete with forklifts, trucks, product flow and pedestrian activities, indicates the onset of the evolution of computer based modelling for safety and productivity optimisation. (Canfield, 2000)
DISCUSSION

Although the presence of forklifts in industrial environments is widely recognised as a hazardous situation, there is a definite lack of supportive statistics. This doesn’t mean that the statistics suggest that forklifts aren’t a problem, it actually indicates that insufficient data and research has occurred in the way of forklift safety.

In North America both the USA and Canada had significant amounts of data available with regard to both forklift accident mechanisms and general safety information. NIOSH has been a key player in the collection of statistical data over a long period, which in effect established it as the benchmark for the quality of accident based information.

Australia’s central OHS body, NOHSC who also keeps forklift-related data, appeared to contradict the data held by NIOSH. Closer analysis of NOHSC’s classification of fatal accidents revealed an unacceptable degree of subjectivity in terms of the determining of causal mechanisms. The product of this inaccuracy was lopsided figures, that blurred the view of the real hazards associated with forklift operation, roll-overs and contact with pedestrians.

Actual accident data for forklifts in Europe was extremely difficult to come by. Only the UK’s Health and Safety Executive appeared to keep any current data with regard to forklift accidents. Whilst the data kept by the Health and Safety Executive was quantitative, the quality of the information was again questionable. Whilst it is understandable that statistics portrayed is dependant upon the level of reported information, it hardly seems likely that for a three year period between 1996-98 there were only 19 reported fatalities, and only one of which being attributed to roll-overs.

Uniformly there was no shortage of information with a regulatory or guidance overtone. This is consistent with the approach, which assumes the answer to improving forklift safety standards lies in the education/training of the operators. This reliance on training as being the answer to reducing the risks associated forklifts is a low-level control, with only a limited probability of success.

Training in conjunction with other administrative controls like improved logistics planning would certainly be an improvement, but where the real gains are to be made will stem from engineering development of the characteristics of the forklift. This would address issues such as stability, proximity and speed control/zoning. Only a multifaceted approach to forklift safety has the potential to influence the broadest spectrum of the market, and make significant improvements in the reduction of forklift related accidents.
Australian Standard 2359.3-1995 initiates the framework for stability testing of counterbalances forklift trucks. Given the wide variety of forklifts, of differing configurations, which all behave individually in dynamic environments, recognising the forklifts stability boundaries is essential in the prevention of roll-overs. Whilst functional diversity is a major strength of the forklift, this doesn’t come without inherent risks. The lack of real time information portrayed to the operator, with regard to how a specific task is impacting on the stability of the vehicle and load, contributes to the occurrence of unsafe acts. This may suggest that there is a more effective means to coordinate safe operating instructions than the current load chart attached to the forklift.

With regard to preventing unsafe acts, which is of course optimal, only Toyota’s new 7-series forklift attempts to control the hazard of stability. Technology referred to as SAS monitors and controls the actions of the vehicle and the mast, to prevent roll-over and falling loads. This initiative by one forklift manufacturer will hopefully stimulate the competition to adopt similar principles, which will in effect improve the stability of the majority of new forklifts that enter industry.

Contact between forklifts and pedestrian workers was revealed as a primary accident mechanism, which can only be effectively controlled if the actions of the forklift are moderated, when in a close proximity to mobile and stationary objects. This is reliant upon a sensing mechanism linked to the mechanics of the forklift. The most likely means of achieving this would be to combine the use of laser detection, with the use of an ‘antilock type’ braking system. This process is dependent upon the application of identity tags, which the laser can recognise and transmit information accordingly, whilst the response of the vehicle needs to safeguard against shifting loads.

Controlling the compliance of personnel tagging is a determinant of the success of this process. The means by which to achieve this revolves around regimented site control, secured boundaries, and effective logistics planning. Consideration of speed limits for specific zones is also a function of logistics planning, which could also be integrated into the vehicles on-board computer much in the way of the proximity system.

With the streamlining of the logistics planning process, brought about by the innovation of computer based 3D modelling, potential trouble spots can be ironed out even before they exist. To ensure that each of the ingredients is factored into the process, the existence of a blueprint for the variety of potential applications would be a beneficial guide. Due to the enormous growth in this area, availability of suitable software packages isn’t an issue. It can be expected that the types of functions that these packages perform will also continue to expand over the coming years.

So as to achieve improvement in the safety performance of forklifts, significant steps need to be taken by government bodies and manufacturers alike. It may be necessary for government bodies to broaden their approach towards forklift safety, so as to promote safety consideration both design and workplace levels. The production of a retro-fit option that addresses stability, proximity and speed is certainly a positive step, but it would be even more effective if it wasn’t a hazard in the first place.
CONCLUSION

There is no shortage of statistics corroborating the degree and severity to which forklifts are involved in workplace accidents. This problem is of a global nature and exists throughout all industries revolving around a core of root causal factors (Janicak, 1999). To date most of the research regarding forklift safety has taken an ergonomic, occupational hygiene and training based approach. Subsequently little advancement has occurred in the way of risk reduction in the form of actual applied interventions.

What is most perplexing is the reluctance of the various forklift stakeholders to adopt similar risk control strategies as initiated in road and aviation. More universal attention needs to be directed towards the issue of forklift stability, so as ‘SAS-like’ technology is viewed as the norm, rather than an exception. This philosophy should also extend address the quality of the information that operators receive when handling loads.

The issue of load stability could be effectively managed by adopting a two-stage process. This should firstly aim to provide continuous data, as to how the movement of raised load impacts on the forklifts safe load-handling limit. This could work in a similar manner to how an ‘attitude indicator’ provides feedback to pilots so as to overcome sensory misconception (Allstar Networks, 2000). The second stage of this process could use the ‘attitude indicator-like’ system to prevent movement of a particular load, when the system senses the action would compromise the overall stability of the forklift.

Development of effective stability and load controls for forklifts should occur as well as, not instead of ROPS/FOPS devices and operator restraint systems. The array of circumstances where these operator protection devices are effective is immense. Not to mention the 20% predicted reduction in fatalities when these controls are implemented together. (NOHSC, 1998)

Poor logistics planning for forklift operation in factory and warehouse environments spawns a mass of ensuing hazards. Collisions between powered industrial vehicles, pedestrian workers and both stationary/mobile objects, are major mechanisms of forklift accidents. The risk of such accidents is further magnified when aisles are obstructed and when the forklift is loaded (Collins et al (c), 1999). Subsequently a need exists to control and alert the forklift to the presence of such potential hazards.

An on-board proximity control system, fully integrated with logistics based speed zoning, would be the most conclusive method of reducing the instance of fatalities occurring as a result of various collisions. Given that most of the necessary ITS technology is already available and that many transport terminals are now computer-modelled prior to installation, the time for such an approach is imminent. (Garibotto et al, 1998)
REFERENCES


Robertson, R (2000): Power Play: Big score with these new powered industrial trucks. Materials Management & Distribution/Bizlink, Rogers Media


Stuckey, S (1996): The smarter forklift. The Engineer


