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Analysis of Forklift Accident Trends within Victorian Industry (Australia)

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Abstract

This paper analyses the frequency of forklift related fatalities and injuries within the Victorian state of Australia for the time period 2000 to 2012. Forklift accidents leading to injury were finely categorised to better understand the occurrence of specific accident types. Forklift fatalities were detailed on a case by case basis and comments were given as to the prevalence of certain accident types. The results from our study were compared with a similar study performed some two decades ago (involving Victorian industry) to see what variations have occurred over time. In order to give validity to this comparison, sensitivities to industrial expansion and the greater adoption of Just in Time (JIT) manufacturing procedures was considered. We also considered the impacts of industrial expansion with regards to the data obtained for our current study (2000 to 2012). This paper highlights the positive impacts safety initiatives have had in reducing forklift related accidents in Victorian industry. Recommendations are finally given as to how further improvements could be made which will also have relevance to the wider globe in general.

Keywords
Occupational safety
Forklifts
Victoria, Australia

Notes
Coloured figures and tables are to be reproduced on the web in colour. Coloured figures and tables are to be reproduced in print in black and white.

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1. Introduction

The counterbalanced rider lift truck, more commonly known as the forklift, is one of the most familiar types of powered machinery used in industry. Its ability to shift heavy loads efficiently has led to its universal application within manufacturing plants, warehouses, freight terminals and trade environments. The standard counterbalanced forklift, similar to the one shown in Figure 1, weighs about three tonnes and has a 2.5 tonne lifting capacity. This equates to a staggering combined weight of up to 5.5 tonnes. For most people intuition suggests that having a foot run over by a sedan would be more harmful than a forklift. Figure 2, as provided by WorkSafe Victoria (2005a), shows that having a foot run over by the front wheel of a loaded 2.5 tonne capacity forklift is an order of magnitude more damaging than a sedan wheel. The former would lead to severe trauma inflicted to the foot with multiple fractures whilst the latter would more likely just cause bruising and swelling.

As Larsson et al. (2003) point out, “In the loaded condition of a 2.5 tonne capacity forklift, the load represented at each front wheel is in the order of 2.5 tonnes”. The crushing capabilities of a forklift do not compare to a sedan. For some people intuition does not suggest this which leads to a distorted view of the perceived dangers.

Forklifts often operate in confined spaces having to manoeuvre within narrow aisles, move in and out of cramped production line stations, ensure not to fall from tight docking platforms, etc. Most critically, pedestrians are often in the nearby vicinity of working forklifts. The forklift operator has a lack of visibility due to blind spots caused by the forklift operator enclosure, forklift mast assembly and the forklift load carried. Such blind spots, as well as large forklift inertias and tight forklift operating areas, combine to make forklifts extremely accident prone. The most frequent accident type leading to injury is a forklift striking/crushing a pedestrian. Such an incident type often leads to severe trauma inflicted to the pedestrian and possibly death.

Larsson and Rechnitzer (1994) conducted a detailed study of forklift incidences within the Victorian state of Australia. The required end outcomes from this research were to advise regulators and industry on priorities for injury prevention. Larsson and Rechnitzer (1994) study analysed injuries associated with forklifts on file with the Accident Compensation Commission, Victoria, for the period of January 1989 to December 1990, as well as the forklift associated fatalities on record with the State Coroner of Victoria for the period of October 1987 to April 1990. According to Larsson and Rechnitzer (1994) study, 15 fatalities (during the period of October 1987 to April 1990) and some several hundred occupational injuries per annum (during the period of January 1989 to December 1990) were attributed to forklifts in Victoria. Table 1 is provided by Larsson and Rechnitzer (1994) and shows frequencies of various forklift accident types that lead to injury within Victorian industry. Also given is the average lost time and average compensation payout which both indicate the severity of various accident types. The descriptions of the forklift accident types used by Larsson and Rechnitzer (1994) in Table 1 are as follows:

- **Hit by forklift** – pedestrian struck/crushed by forklift.
- **Fall from/by forklift** – fall from vehicle, fall from load, fall from raised tynes and fall from climbing on the forklift outside cabin.
- **Other forklift injury** – includes collisions, overturns, sudden stops and hands/fingers getting caught and crushed by the mast assembly.
- **Overexertion (strains)** – includes from driving the vehicle, from getting in and out of the vehicle and handling heavy forklift equipment.

It should be noted that injuries unrelated to powered forklift trucks have not been taken into consideration by Larsson and Rechnitzer (1994), these include injuries sustained from use of manual handling equipment such as pallet movers, etc. From Table 1 it can be seen that only 224 incidences from 314 were forklift related and did not involve manual handling equipment or were unclear/unrelated. Larsson and Rechnitzer (1994) obtained 1,267 injuries coded as forklift related for the time period of January 1989 to December 1990 and filtered this data to obtain the figures shown in Table 1. The nature of the filtering involved a random process of selecting every third, fourth and tenth case where injury times were 60 days or less. No filtering was performed for injury times greater than 60 days. Larsson and Rechnitzer (1994) considered a 25% sample size as satisfactory. The filtering served to make more clear the incidence of frequent/severe accident types that require attention. From Table 1 it is evident that a pedestrian being struck/crushed by a forklift is the most frequent forklift accident type.

In the past decade WorkSafe Victoria has taken considerable measures to try and reduce forklift accidents from occurring in industry. This involved launching a marketing campaign on forklifts and pedestrian safety in 2003. This was followed by the Pedestrian Forklift Safety Project which later evolved into the Forklift Instability and Traffic Management Project. The Forklift Instability and Traffic Management Project lasted for four years and involved education, advertisement campaigns, the production of guideline materials, field inspections,
stakeholder group seminars and policy development. No similar study to that of Larsson and Rechnitzer (1994) has been performed for recent times in Victorian industry to determine what improvements have been realised, especially in light of WorkSafe Victoria’s safety efforts in the past decade. To undertake this study, we submitted a freedom of information request to WorkSafe Victoria to obtain forklift accident reports (involving both injuries and fatalities) for Victorian industry as far as records go back. As a result of this, we received approximately 2,500 reports involving injuries, near misses and material damage going back to 1997. We also received 48 fatality reports going back to 1985. Based on the received forklift injury and forklift fatality data we have:

- Categorised forklift accident types that caused injury and performed a frequency analysis (spanning the time period 2000 to 2012). The degree of categorisation was such that various accident types were not lumped into a single category. This was performed in order to better understand the occurrence of specific accident types that caused injury. We have also compared our results (in total) with Larsson and Rechnitzer (1994) study (covering the period January 1989 to December 1990) to see what variations have occurred over time.
- Commented on the prevalence of certain forklift accident types that lead to fatalities (covering the period 2000 to 2012). We have also compared this data with the fatality results from Larsson and Rechnitzer (1994) study (covering the period of October 1987 to April 1990) to see what variations have occurred over time.

We also have taken into consideration the industrial output changes in Victoria when comparing the results of Larsson and Rechnitzer (1994) study with our current results. This is because, in general, a hypothetical doubling of forklift intensive industry with respect to two decades ago, with similar forklift incident statistics for both time periods, would not mean that no progress regarding forklift safety has been made, rather it would mean that significant progress has been made. Sensitivities to the greater adoption of Just in Time (JIT) manufacturing was also considered as this process results in greater forklift activity and hence the higher probability for forklift accidents. The effects of industrial expansion were also looked at for our current study (spanning the time period 2000 to 2012).

We finally draw relevant conclusions firstly for our study on its own and secondly on how these results compare to Larsson and Rechnitzer (1994) study (involving data from some two decades ago). This is then followed by giving appropriate recommendations. It should be mentioned that although this paper specifically focuses on forklift accidents in Victorian industry, the results will have relevance for forklift accidents in general and therefore would have global significance.

2. Material and Methods

2.1 Obtaining forklift incident reports and other data from WorkSafe Victoria

The Victorian Workcover Authority (currently trades under the name WorkSafe Victoria) is a statutory authority of the Victorian state government in Australia and regulates a wide range of parliamentary acts including the Accident Compensation Act 1985, the Accident Compensation (Occupational Health and Safety) Act 1996, the Accident Compensation (WorkCover Insurance) Act 1993, the Workers Compensation Act 1958 and the Dangerous Goods Act 1985. WorkSafe Victoria carries out state wide workplace safety inspections and prosecutes any workplace safety violations. WorkSafe Victoria records all workplace incidences involving injuries and fatalities occurring in the state of Victoria.

Table 1: Results from Larsson and Rechnitzer (1994). Injury type frequencies, average lost time and average compensation paid in the sample for Victorian industry (January 1989 to December 1990).

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Frequency</th>
<th>Average Lost Time (days)</th>
<th>Average Compensation ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hit by forklift</td>
<td>101</td>
<td>99.5</td>
<td>11,578</td>
</tr>
<tr>
<td>Fall from/by forklift</td>
<td>50</td>
<td>104.3</td>
<td>11,475</td>
</tr>
<tr>
<td>Other forklift injury</td>
<td>32</td>
<td>93.1</td>
<td>9,263</td>
</tr>
<tr>
<td>Overexertion</td>
<td>41</td>
<td>60.9</td>
<td>6,137</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>224</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual handling</td>
<td>36</td>
<td>142.6</td>
<td>12,730</td>
</tr>
<tr>
<td>Unclear/unrelated</td>
<td>54</td>
<td>102.6</td>
<td>9,810</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>314</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
To obtain dated forklift incident reports from WorkSafe Victoria, a freedom of information request was submitted. We subsequently received approximately 2,500 reports, which were coded as forklift related, involving injuries, near misses and material damage going back to 1997. We also received 48 fatality reports which were coded as forklift related as far as records go back to 1985.

We also requested in the freedom of information form all the injury compensation that was paid out for forklift related accidents in Victorian industry for the year 2005. The reasons for this request are explained in Section 4, Subsection 4.6. It should be noted that we intended to determine the average injury compensation cost paid out for various forklift accident types in our current study, much like Larsson and Rechnitzer (1994) did as shown in Table 1. However, there were difficulties with accurately cross referencing individual injury compensation costs with individual forklift injury reports. This is due to the fact the date an injury report was made did not necessarily correspond to the date the associated compensation was paid out to. We tried to obtain the names of the victims involved in the injury reports (which were omitted) and the names of the recipients of injury compensation (which were omitted) to try and overcome this issue. However, privacy laws in Victoria did not permit the release of such details.

2.2 Categorising forklift injury incidences

Table 2 shows the categorisation of forklift accident types we use where an injury is involved. The examples and notes within this table serve to allow the forklift injury results presented in this paper to be reproduced by others. The nature of the forklift injury accident reports received from WorkSafe Victoria were brief summaries, an actual example is as follows: “Male employee, 35yrs, was working at the market setting up display ready for sales. A forklift from another stall has apparently reversed and hit him, to Royal Melbourne hospital”. Some forklift injury reports were difficult to categorise because of this brevity. In this instance the most appropriate category was designated if possible. Such cases were rare and did not have a significant impact on the overall statistical analysis. If the report was not practical to categorise then designation ‘11’ (other) was applied from Table 2. Also, sometimes a report fitted into multiple categories. In this case the most appropriate category was used from Table 2, again such cases were rare and did not have a significant impact on the overall statistical analysis. Struck/crushed by forklift (designation four from Table 2) took precedence over all other designations except where the forklift has tipped over and crushed the driver in which case the appropriate tip over designation was applied. Injuries resulting from handling equipment (such as pallet movers) were not considered in the statistical analysis. Also, no electric motor hand trucks were considered. Only injuries involving forklifts and narrow aisle forklifts were considered in the statistical analysis.

2.3 Categorising forklift fatality incidences

Forklift fatalities were not frequent enough to warrant in-depth categorisation yielding meaningful trends. Rather, all forklift fatality incident reports are provided in Section 4 of this paper and comments are given as to the prevalence of certain accident types. Only fatalities involving forklifts and narrow aisle forklifts were considered.

3. Theory: Industrial Output Measures

In order to compare the results of Larsson and Rechnitzer (1994) work with our study, consideration must be given to the industrial output changes between the times both studies were conducted. As was mentioned heretofore, if forklift intensive industrial output in Victoria significantly increased in the time period between these studies, then this would generally translate into more forklift activity and hence a higher potential for accidents. Therefore, if the amount of forklift accidents did not vary over time whilst the industrial output significantly increased, it would indicate that positive inroads have been made to prevent forklift accidents occurring.

A state’s industrial output is generally made up of three sectors; mining, manufacturing and services. The gross domestic product (GDP) is a measure used for a state’s industrial output over a given period of time (generally a year). The GDP is the market value of all goods and services produced within a given period of time by a state. It is determined using the following equation:

\[
GDP = GVA + T - S, \quad (1)
\]

where,

- \(GDP\) is the gross domestic product
- \(GVA\) is the gross value added
- \(T\) is the taxes on goods and services
- \(S\) is the subsidies on goods and services.
<table>
<thead>
<tr>
<th>Designation</th>
<th>Incident Description, Injury Involved</th>
<th>Examples and Relevant Notes Where Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Crushed within forklift mast assembly</td>
<td>EXAMPLE: Male worker (30) was trying to fix a forklift (attempted to fix a lifting chain after it has come off of its pulley). He has climbed up and got the chain back on the pulley and the full weight has dropped onto the chain and severed his right thumb above the knuckle. Taken to St Vincents hospital by ambulance. Scene has been disturbed and operations have continued.</td>
</tr>
<tr>
<td>2</td>
<td>Struck/crushed by object (not forklift) as a result of forklift loading/unloading</td>
<td>EXAMPLE: Hand resting on truck - crushed the tips of three fingers when a forklift placed load on top of fingers when unloading onto truck. He was taken via ambulance to hospital and is currently in surgery. NOTES: Clearly in process of loading/unloading. Even if other object shunted onto someone, if in the process of loading/unloading this designation is used.</td>
</tr>
<tr>
<td>3</td>
<td>Forklift crash and operator injured (forklift did not tip over)</td>
<td>EXAMPLE: A 20 year old male employee was operating a forklift to unload a container. Whilst moving the pallet from the container to the stock's designated area he has driven into a pole. As a result it is suspected that the driver has hit his head against the steering wheel of the forklift and been knocked unconscious. An ambulance has been called. NOTES: If injury resulted from dangling limb outside forklift then this designation used.</td>
</tr>
<tr>
<td>4</td>
<td>Struck/crushed by forklift</td>
<td>EXAMPLE: A 47 year old male employee was conducting a security foot patrol and guiding a truck into a loading bay when he was struck by a loaded forklift. NOTES: Struck/crushed by forklift takes precedence over all other designations except where forklift has tipped over and crushed driver. If forklift had to brake suddenly and load struck/crushed pedestrian, then this designation is used. Also if operator stuck/crushed by own forklift then this designation is used.</td>
</tr>
<tr>
<td>5</td>
<td>Struck/crushed by object (not forklift) as a result of forklift collision</td>
<td>EXAMPLE: A 60 year old worker stepped off a motorised trolley to work on a machine when a forklift collided with the trolley, pushing it against a pallet which in turn jammed the worker left foot against the pallet. Ambulance took worker to hospital. NOTES: This incident type involves the forklift colliding with an object. The object and not the forklift then strikes/crushes a person (not operator). If during loading/unloading then designation '2' is used (if unsure, this designation is used).</td>
</tr>
<tr>
<td>6</td>
<td>Forklift tip over</td>
<td>EXAMPLE: A male forklift driver, 51yrs, was driving forklift when it appears to have tipped onto its side. Preliminary investigation still in progress. Cause not known. NOTES: If forklift dropped from a height and tipped over, then designation '8' is applied.</td>
</tr>
<tr>
<td>7</td>
<td>Forklift drops from height and does not tip over</td>
<td>EXAMPLE: The forklift operator was driving down the ramp when he reversed off the dock, the drop was 1.5-1.8 metres. Driver appears to be ok at this stage, however the forklift landed on all 4 tyres.</td>
</tr>
<tr>
<td>8</td>
<td>Forklift drops off height and tips over</td>
<td>EXAMPLE: Forklift vehicle (reach truck) was being loaded onto a low loader via reverse and forklift fell off ramp. Driver was not injured and forklift fell on side and has been cordoned off. Incident already has been notified.</td>
</tr>
<tr>
<td>9</td>
<td>Forklift drops off height and unsure whether tipped over or not</td>
<td>EXAMPLE: Forklift loading truck, truck drove away whilst forklift was going into truck. Forklift fell to ground approximately one metre. Forklift driver jumped off.</td>
</tr>
<tr>
<td>10</td>
<td>Slips, trips, sprains and strains moving about forklift</td>
<td>EXAMPLE: A 40 year old male stepped up onto a forklift and injured his right achillies. Taken to doctor for scans and referred to surgeon for surgery. NOTES: Fall from risen tynes included.</td>
</tr>
<tr>
<td>11</td>
<td>Other (all forklift related and injury involved)</td>
<td>EXAMPLE: An employee’s hand struck by the blades of the cooling system on a forklift truck. NOTES: If manual handling on forklift tynes and injury resulted then included in designation 11. If manual handling incident occurred away from the forklift then viewed as non-forklift related and therefore no designation is used.</td>
</tr>
</tbody>
</table>
An improvement the chain volume measures approach makes with respect to the constant price estimates approach is that a lengthy period of services prices are used for say each year. A compounding process is then finally employed so that comparisons can be made from one year to another. This is achieved by not using constant prices for goods and services. Rather, a series of goods and services prices are used for say each year. A compounding process is then finally employed so that comparisons can be made from one year to another. A detailed description of the chain volume measures and the constant price estimates approaches are provided in (Australian Bureau of Statistics, 2003).

The Australian Bureau of Statistics (ABS) currently use chain volume measures as the official measure to determine industrial growth rates. We have also used this measure to indicate the level of forklift intensive industrial output (in terms of GVA) in Victoria during the time Larsson and Rechnitzer (1994) conducted their study and for the time of our current study. The Victorian industrial output is divided into a number of areas from ABS reports (Australian Bureau of Statistics, 2012). Larsson and Rechnitzer (1994) study identified the following areas as the main contributors to forklift accidents (92% from a sample of 224 injury reports).

- Manufacturing
- Wholesale trade
- Retail trade
- Transport, postal and warehousing.

We only consider these areas in our analysis.

4. Results and Discussions

4.1 Forklift injury incident results (spanning years 2000 to 2012)

The forklift injury reports from WorkSafe Victoria were categorised as described in Section 2 and shown in Table 2. Three two year periods were analysed spanning approximately the past decade. Table 3 shows the results of the frequency analysis. It should be noted that not all incident reports explicitly described that an injury had in fact occurred. An example is as follows: “A truck from **** transport was being loaded by a forklift when the driver of the truck was hit by the pallet on the forklift and fell to the ground hitting his head on the ground”. Another example is, “Walking across car park. Hit by forklift. Sent to doctor and hospital”. In these cases an injury has not been explicitly stated, however it can be reasonably assumed that they did in fact occur. To indicate such scenarios an injury assumed column is included in Table 3 for each period of two years. It should be noted that the overwhelming majority of reports, where it was not clearly stated an injury did not occur, fitted in either of the ‘injury’ or ‘injury assumed’ categories. Only in rare instances was this not the case. Therefore, the statistics in Table 3 are sound indicators to the general frequency of specific forklift accident types that lead to injury.

From Table 3 it is evident that the total injuries for each two year period observed was 212, 183 and 211 in chronological order. This may suggest that there was no real reduction in total injuries over the decade or so duration. Seeing as the time span in question is approximately a decade, an effort should be made to try and assess what impacts industrial output changes (where frequent forklift accidents occur) may have had on the data. We examine this as follows. Table 4 shows the annual gross value added (GVA) for various segments of Victorian industry that tend to have high levels of forklift accidents, chain volume measures have been used. The data was obtained from the ABS as detailed in Section 3. The first column of data in Table 4 is related to the period of Larsson and Rechnitzer (1994) study. The remaining columns have relevance to our current study. From Table 4 it is apparent that the total level of industrial output where forklift accidents tend to be high has gradually increased. From June 2001 to June 2011 an approximately 16% increase can be seen. In this period manufacturing output was rather steady with the main changes being increases in wholesale trade, retail trade and transport/postal/warehousing. The fact that there were no significant decreases in either of these sectors is important. This is because not all of the sectors are weighted equally in terms of the
potential to cause forklift accidents. Therefore, it is possible that industrial output decreases in certain sector(s) and industrial output increases in other sector(s) could yield a situation where the collective industrial output did rise, however the overall potential for forklift accidents in fact decreased. Given there were no significant reductions in either of the sectors, it can be deduced that the 16% increase from June 2001 to June 2011 in total industrial output from Table 4 would have increased the likelihood of forklift accidents. Therefore, one may now conclude that the total injury data from Table 3 did show a decline over the entire duration. However, this conclusion is not valid for the reasons described as follows. The 16% increase in industrial output may not be high enough to significantly overcome noise/variability in the data and make it obvious that a decline had occurred. Also, seeing as there are only three data points from Table 3 regarding total injuries, this small amount is insufficient to determine the level of noise/variability in the data. Therefore, it is difficult to conclude with certainty that there were reductions in total injuries from Table 3 over the entire duration.

The second time period observed in Table 3 saw a considerable drop in total forklift accidents. This drop cannot be explained by variations in industrial cycle as ABS reports (Australian Bureau of Statistics, 2012) show that manufacturing, wholesale trade, retail trade and transport/postal/warehousing had no cyclic variations in the decade of interest.

Table 3 shows that a person being struck/crushed (designation three) by a forklift is the most prevalent accident type leading to injury within Victorian industry over the past decade or so. This accident type had a frequency of 85, 78 and 73 occurrences for each two year period observed in chronological order. A steady decline is apparent with a 14% reduction spanning the entire duration. As with before regarding
total injuries, we cannot conclude with certainty whether there was or was not an actual decline in pedestrian struck/crushed injury incidences. From Table 3 we also see that a forklift tipping over saw an apparent improvement, a 25% decline over the entire duration. This form of accident type tends to be severe in terms of causing a relatively high number of fatalities, this will be shown later on in the paper. Again, we cannot conclude with certainty whether there was or was not an actual decline here. The greater usage of seat belts no doubt would help prevent this accident type as promoted by WorkSafe Victoria (2005a) and WorkSafe Victoria (2005b).

An interesting thing to note from the data shown in Table 3 is that forklift collisions make up approximately 50% of the forklift incidences leading to injury for each time period. That is, categories 3, 4 and 5 involve a forklift collision of some sort and causing injury. These categories together make up 50%, 51% and 47% of the total forklift injuries for each two year time period observed in chronological order. On average a collision related forklift accident leading to injury currently occurs every week in Victorian industry.

4.2 Comparison of current forklift injury results (spanning years 2000 to 2012) with past data (January 1989 to December 1990)

The results reported by Larsson and Rechnitzer (1994) provide forklift injury statistics for Victorian industry over a two year period (January 1989 to December 1990). Their results are shown in Table 1. From these results it is not clear what the total amount of forklift related injuries was during that period. This is because, as mentioned heretofore, Larsson and Rechnitzer (1994) performed a filtering process for injury data that was 60 days or less to highlight frequent/severe accident types. Given that forklift related injury reports from WorkSafe Victoria currently go back to only 1997, it was not possible for us to obtain earlier data. However, we can still infer an accurate estimate of the total number of forklift injuries that occurred from Larsson and Rechnitzer (1994) study in the manner described as follows. For the given period, Larsson and Rechnitzer (1994) obtained 1,267 injury reports that were coded as forklift related for Victorian industry. After filtering, the number was reduced to 314 (25% sample). Of this 314, only 224 were considered appropriate as the remaining either involved the use of manual handling equipment or were unclear/unrelated. Dividing 224 by 314 gives approximately 0.71. Multiplying this figure by the total number of injury reports received (1,267) yields approximately 900. Therefore, this figure of 900 could be used as the number of valid forklift injury reports received by Larsson and Rechnitzer (1994) in their study. However, it may also be possible that the 71% ratio of valid injury reports used was a statistical anomaly and that the real ratio is much lower. To determine whether this was the case, we performed the following statistical analysis. If we assume that the number of valid injury reports from the population of 1,267 is 811 (approximately 64%), then the mean and standard deviation of the discrete probability distribution giving the number of valid injury reports from a sample of 314 can be determined according to the following equations:

\[
\mu = \frac{nK}{N} \tag{2a}
\]

\[
\sigma = \sqrt{\frac{nK(N-K)(N-n)}{N^2(N-1)}} \tag{2b}
\]

where,

- \(\mu\) is the mean
- \(\sigma\) is the standard deviation
- \(N\) is the population size
- \(n\) is the sample number
- \(K\) is the number of successes in the population.

Equations (2a) and (2b) are applicable for a hypergeometric distribution (Forbes et al., 2011) which is relevant here seeing as sampling without replacement is being performed, that is, 314 injury reports are being selected from a population of 1,267 without replacement. Based on \(N=1,267, n=314\) and \(K=811\), the mean and standard deviation is 200.99 and 7.379 respectively according to Equations (2a) and (2b). We see here that 224 valid injury reports falls about three standard deviations from the mean. To determine the probability of obtaining 224 valid injury reports in this case, the hypergeometric probability mass function (Forbes et al., 2011) can be used which is as follows:

\[
P(x) = \frac{{c_\kappa}^x}{{C_\kappa}^N}, \tag{3}
\]
where,

\[ x \] is the number of successes in the sample

\[ C \] is the combination operator.

Solving Equation (3) for \( x=224 \) valid injury reports gives a probability of 0.0387% which translates to an approximately one in 26 chance. Two hundred and twenty four was the amount of valid injury reports that Larsson and Rechnitzer (1994) obtained from their sample of 314 and hence it is unlikely this figure would have been attained if the ratio of valid injury reports was approximately 64% of the 1,267 population. Therefore, a cautious estimate of the number of valid injury reports received by Larsson and Rechnitzer (1994) would be 811 of the 1,267 total received (approximately 64%). If we used a figure of 722 (approximately 57% of 1,267) and repeated the steps mentioned previously, the mean and standard deviation of the hypergeometric distribution would be 178.933 and 7.612 respectively. We see here that 224 falls around six standard deviations from the mean. The chances of obtaining 224 in this case is somewhere in the vicinity of one in 13,000,000 (virtually impossible). There is only some 11% difference between 722 and the 811 figure used previously. This shows that the 811 figure is very close to a virtually impossible scenario as 722 gives an approximately one in 13,000,000 million chance of obtaining 224 valid injury reports. We therefore take 811 to be a cautious estimate of the total number of valid injury reports received by Larsson and Rechnitzer (1994) and use this figure throughout the rest of the paper.

The results from our recent study (view Table 3) showed that annually there were approximately 100 forklift accidents leading to injury that occurred in Victorian industry over the past decade or so. Comparing this with the 400 (based on a cautious estimate) that approximately occurred annually in the time Larsson and Rechnitzer (1994) conducted their study (January 1989 to December 1990), it is apparent that a significant reduction has occurred between the two time periods. Judging by this comparison alone, an approximately four fold reduction has been achieved.

From Table 4 it is evident that there was roughly a 33% increase in industrial output (where forklift accidents are frequent) from June 1990 to June 2011. In this period, manufacturing output was rather steady with the main changes being increases in wholesale trade, retail trade and transport/postal/warehousing. Given there was no significant reductions in either of these sectors (the importance of this was explained heretofore), it can be deduced that the 33% increase from June 1990 to June 2011 in total industrial output from Table 4 would have increased the likelihood of forklift accidents. In this case the approximately four fold reduction in forklift accidents leading to injury, based on a conservative approach, is somewhat understated.

Just in time (JIT) manufacturing is a process where the concept of manufacturers storing large quantities of inventory is replaced with goods being manufactured on customer demand and delivered shortly thereafter. This process has numerous advantages. One notable advantage in many cases is that financial borrowing costs are reduced as a result of not paying interest for money borrowed to create large stores of inventory. Clarke and Mia (1993) report that the JIT manufacturing process was first adopted in Australia in 1982 and has gradually increased since then. In their study, they stated, “Overwhelmingly, Australian manufacturers have adopted JIT to reduce inventory related costs”. This manufacturing process change in paradigm has resulted in smaller batches of goods manufactured on a more frequent basis. Rechnitzer and Larsson (1992) suggest that this increases forklift activity. From this, again the approximately four fold reduction in forklift accidents leading to injury (based on a conservative approach) is somewhat understated as more JIT adoption by Victorian industry would have taken place after Larsson and Rechnitzer (1994) period of study (January 1989 to December 1990).

It is apparent that there has been a significant reduction in forklift related injuries occurring in Victorian industry from the time of Larsson and Rechnitzer (1994) study to current times. The safety initiatives conducted by what is now called WorkSafe Victoria have no doubt had a significant influence in reducing forklift accidents leading to injury within Victorian industry.

### 4.3 Forklift fatality incident results (2000 to 2012)

Table 5 shows Victorian forklift fatality incident reports as provided by WorkSafe Victoria for the time period 2000 to 2012. There are 18 fatalities in total. Fourteen of these fatalities occurred within the first seven years with the remaining four fatalities occurring within the last five years. It seems apparent that there has been a significant decline in forklift related fatalities over the past decade or so within Victorian industry. To further highlight this, Figure 3 plots cumulative fatalities vs year and it is evident that the quadratic trend line tapers off with time. The equation of the quadratic trend line in Figure 3 is:

\[
F = -0.0764236t^2 + 307.9355644t - 310174.5264539
\]  

(4)
Table 5: Victorian forklift fatality incident reports from 2000 – 2012 as provided by WorkSafe Victoria.

<table>
<thead>
<tr>
<th>Year</th>
<th>Incident Description, Fatality Involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>A man was attempting to use a forklift to unload damaged pieces of equipment from a low loader. He has tried to exit the forklift stepping on a chain on the floor causing his foot to slip and become trapped under the pedals. He then struck his head.</td>
</tr>
<tr>
<td>2000</td>
<td>A man was crushed as a result of a load of packing crates falling upon him. This was dislodged by a forklift truck working on the opposite side of the truck.</td>
</tr>
<tr>
<td>2000</td>
<td>A man was trapped beneath the forklift truck when he alighted from the forklift and it rolled forward trapping him.</td>
</tr>
<tr>
<td>2001</td>
<td>A man was loading semi-trailers in a loading dock when he was crushed between a truck and an elevated loading platform.</td>
</tr>
<tr>
<td>2001</td>
<td>A man was crushed under a number of packs containing glass which had slipped off the tynes of a forklift.</td>
</tr>
<tr>
<td>2002</td>
<td>No fatalities recorded.</td>
</tr>
<tr>
<td>2003</td>
<td>Male crushed under a forklift. Deceased attempted to jump out of the cabin prior to the forklift falling on its side resulting in crush injuries by the forklift safety cage.</td>
</tr>
<tr>
<td>2003</td>
<td>A male had been lifted by a forklift to carry out repairs to an overhead conveyor system. He was crushed between the mast and roll cage of the forklift while attempting to climb back down. It appears that the deceased may have stepped on the lever lowering the mast.</td>
</tr>
<tr>
<td>2004</td>
<td>A male fell off a forklift while filling a hopper/silo and died some hours later in hospital.</td>
</tr>
<tr>
<td>2004</td>
<td>A male sustained fatal injuries when the forklift he was operating overbalanced and tipped crushing him between the ground and the forklift roll cage.</td>
</tr>
<tr>
<td>2004</td>
<td>A male sitting on a forklift being driven along a concrete driveway area between two factories was thrown off the forklift and sustained fatal injuries.</td>
</tr>
<tr>
<td>2005</td>
<td>A male was struck by a forklift and subsequently died as a result of the injuries sustained.</td>
</tr>
<tr>
<td>2005</td>
<td>A male operating a forklift within the factory area has struck a pole resulting in the forklift to tip crushing the operator beneath the forklift.</td>
</tr>
<tr>
<td>2005</td>
<td>A male truck driver (being loaded by forklift) was struck on the head when a metal module (4ft x 4ft x 6ft) used to transport chickens fell off the truck whilst being loaded.</td>
</tr>
<tr>
<td>2006</td>
<td>A male has sustained life threatening injuries when the forklift he was operating struck an overhead beam and tipped trapping him beneath the forklift, he died later.</td>
</tr>
<tr>
<td>2007</td>
<td>No fatalities recorded.</td>
</tr>
<tr>
<td>2008</td>
<td>An employee fell down in factory and hit his head. At the time a forklift was backing back. The person informed is not sure at this stage if worker jumped out of way to avoid forklift or forklift has hit him. He was admitted to the hospital. The worker has died in the hospital.</td>
</tr>
<tr>
<td>2009</td>
<td>A male truck driver delivering instant turf to a private property sustained fatal injuries when the forklift he was using to unload the turf flipped onto its back. Deceased was crushed between the seat and the mast of the forklift.</td>
</tr>
<tr>
<td>2010</td>
<td>A male identified as a forklift driver/supervisor sustained fatal injuries when a large and heavy item of freight fell from a forklift whilst being unloaded from a semi-trailer.</td>
</tr>
<tr>
<td>2011</td>
<td>A male employee sustained fatal head injuries as a result of being struck on the head by a falling hoist carriage which was dislodged from a gantry crane by a moving forklift.</td>
</tr>
<tr>
<td>2012</td>
<td>No fatalities recorded.</td>
</tr>
</tbody>
</table>

Figure 3: Victorian forklift fatalities from 2000 to 2012, cumulative total.
where,

\[ F \text{ is the cumulative fatality total} \]
\[ t \text{ is the year.} \]

Pearson’s correlation coefficient for the trend line in Figure 3 is approximately 0.99 which indicates that the fit is sound (values vary from zero to one for positive growth with one being a perfect fit). Applying some basic calculus to Equation (4) we can determine the rate of fatalities per year for the years 2000 and 2012 for comparison. This is achieved as follows. Firstly, the derivative of Equation (4) is taken giving \( \frac{dF}{dt} = -0.1528472 t + 307.9355644 \). Substituting the years 2000 and 2012 into this equation yields 2.24 fatalities per year and 0.41 fatalities per year respectively. This indicates that forklift fatalities within Victorian industry have significantly declined over the past decade or so, even when the industrial output was increased by 16%. The data shows that safety campaigns have reduced the likelihood of forklift fatalities.

Five of the fatalities shown in Table 5 clearly involved the forklift tipping over and the operator being crushed. Two of these incidences was preceded by the forklift striking an object and then overturning. Three more fatalities resulted from some sort of forklift related collision incident. A further three fatalities shown in Table 5 clearly involved being crushed by a falling object whilst the forklift was loading/unloading. The remaining fatalities in Table 5 either did not clearly fall into the aforementioned categories or were not relatively frequent. In general, forklift fatalities within Victorian industry were not frequent enough to determine any meaningful trends for specific accident types over the past decade or so.

4.4 Comparison of forklift fatality results (2000 to 2012) with past data (January 1989 to December 1990)

The results from Larsson and Rechnitzer (1994) study showed forklift fatality statistics for Victorian industry during the period of October 1987 to April 1990. In this approximately two and a half year period a staggering 15 fatalities were reported. Compare this with the 18 that occurred in the last 13 years within Victorian industry (view Table 5) and it is obvious that significant progress has been made to prevent forklift related fatalities between the two time periods. As it was explained earlier, this improvement is somewhat understated in light of the 33% industrial expansion over time as well as the greater adoption of JIT.

Four of the reported fatalities in Larsson and Rechnitzer (1994) study involved collisions with pedestrians. Five of the fatalities involved the operator getting crushed or run over by their own forklift whilst they were outside of their vehicle. This type of fatal accident was not significant in our current data. However, a fatality resulting from a forklift tipping over and crushing the operator was more significant in our current data as oppose to Larsson and Rechnitzer (1994) data.

4.5 Recommendations for further reducing forklift accidents

It was previously determined (view Table 3) that approximately 50% of forklift accidents leading to injury within Victorian industry throughout the period 2000 to 2012 resulted from some sort of collision incident. This form of accident leading to injury was by far the most prevalent. It was also shown that five out of the 18 fatalities that occurred within Victorian industry throughout the period 2000 to 2012 resulted from some sort of collision related incident, a relatively high proportion. Therefore, in order to significantly improve forklift accident statistics within Victorian industry, greater attention should be given in trying to reduce collision incidences. Efforts by WorkSafe Victoria have been initiated to reduce this form of accident type which are described as follows. Larsson et al. (2003) state “Speed limiting is also vital to prevent collision with other equipment or pedestrians”. Hence, operating a forklift within safe speed limits is an important factor with regards to reducing collisions. Many forklift manufacturers provide speed limiters with battery powered forklifts. There are various after-market speed limiters which can be used for forklifts with internal combustion engines. WorkSafe Victoria (2005a) has promoted the use of smart forklifts which have speed limiting devices. Larsson et al. (2003) also point out that speed limiting devices are not the only option, speed alert monitors can also be used. WorkSafe Victoria (2005a) recommends employers should establish appropriately sized pedestrian exclusion zones where forklifts are intended to operate. The size of the exclusion zones would depend on the speed of the forklift. Some other safety measures WorkSafe Victoria (2005a) encourages for reducing collision injuries/fatalities are changing operator behaviour, using clear/visible speed signs, using safety barriers and using containment fences. Changing operator behaviour involves things such as training the operator to sound the horn before approaching an intersection, training the operator to go in reverse and look over his shoulder when a forklift’s load obstructs the frontal field of view, etc.

In addition to using the safety measures mentioned previously, electronic proximity warning systems could also be developed that sound an alarm when the forklift is dangerously approaching a pedestrian or object. Upon hearing this alarm the operator would react by slowing down the forklift’s speed. Such a system would greatly enhance the hazard management measures available with regards to dealing with forklift...
collisions. Proximity control systems have been developed previously for forklifts however each has its drawbacks. These are discussed as follows.

Larsson et al. (2003) prototyped a radio frequency identification (RFID) system to signal to the forklift operator the presence of person(s) in the nearby vicinity of a forklift. This system requires people to wear RFID tags (also known as transponders) and forklifts to be fitted with two way radio transmitter/receivers (also known as interrogators). The interrogator initially transmits a radio wave. A transponder in the immediate vicinity can receive this radio wave and transmit its own radio wave thereafter. The interrogator then receives the transponder signal indicating its nearby presence. A warning is then given to the forklift operator. The nature of the RFID signal used causes limitations for such a system which is described as follows. The RFID signal generally operates in the ultra high frequency (UHF) range between 860 to 960 MHz. This is because the size of the transponder antenna is limited. In general, for an antenna to operate efficiently it must have a length equal to half the wavelength of the signal it is intended to either transmit and/or receive. Seeing as RFID tags are small, this then limits the size of the antenna, hence the use of UHF signals in RFID. A disadvantage of UHF signals is that they cannot penetrate water. Humans are made from 70% fluids which means someone wearing an RFID tag needs the tag to be facing the forklift and not be obstructed by any bodily parts to completely ensure detection. To combat this, Larsson et al. (2003) suggest using special tag solutions stitched into garments that can be detected from all angles. The exact details/practicalities of this concept were not discussed.

Another disadvantage with RFID systems is that the exact location of a person wearing an RFID tag relative to a forklift is unknown. That is, it can only be understood that the person has come within the detectable range. The problem this poses for a forklift application is that often people will be within the detectable range and in no apparent danger. An example would be a forklift travelling past people who are on the other side of a safety rail. The forklift operator can become desensitized to warning signals because of this and not react appropriately in the event of a safety critical situation. The RFID system is also limited to pedestrians in the main, therefore collision avoidance with general objects is not possible. To our knowledge, the use of the described RFID system for pedestrian detection has not yet been adopted within the forklift realm.

Lecking et al. (2005) developed an autonomous robotic forklift where laser scanners are implemented to measure distances to obstructions. They use multiple 2D laser scanners that are manufactured by SICK (popular benchmark supplier) which retail for several thousand dollars (AUD) each. The average cost of a new 2.5 tonne capacity forklift is approximately $25,000 (AUD). The cost of multiple 2D laser scanners is a sizeable amount relative to a new forklift. It is apparent then that it is cost inhibitive to use this approach for forklift collision avoidance. The question then is asked “what is a reasonable price for a proximity control system for a forklift application”? This matter is examined in the following subsection.

4.6 Consumer price point analysis for electronic forklift proximity warning system

The amount of injury compensation that was paid out to forklift related accidents in the year 2005 for Victoria was $2,735,054 (this information was received from WorkSafe Victoria after a freedom of information form was submitted). Considering that approximately 50% of forklift accidents were found to result from some sort of collision related incident in the last decade or so (view Table 3 designations three, four and five) and that Larsson and Rechnitzer (1994) study indicated that this accident type tended to have relatively high compensation payouts (view Table 1), we, for the purpose of this general analysis, assume that approximately half of the injury compensation costs for the year 2005 were attributed to forklift collision related incidences. According to WorkSafe Victoria (2005b) there were approximately 85,000 forklifts in operation within Victorian industry in 2005. Based on half of the injury compensation costs for the year 2005 being attributed to forklift related collisions, approximately $16.09 was therefore paid out per forklift for collision related compensation in the year 2005. Over the average lifespan of a forklift, say ten years, this equates to $160.9. Swartz (1999) gives the following relevant quote with special emphasis to forklifts, “Studies have shown that for every insured dollar spent on medical and workers compensation costs, an additional four to five dollars could be tackled on to the injury in indirect or uninsured costs. Depending on the industry involved, say a high tech employer who employs highly skilled employees, the indirect costs could easily be 10 to 15 times that of direct costs”. The indirect costs Swartz (1999) refers to are costs associated with investigation time, claims processing, interruption of work process, retraining of the injured employee upon their return, medical visits upon return, litigation expenses, etc. Taking a conservative factor of two according to Swartz (1999), the $160.9 figure determined previously becomes some $321.8. This amount represents the average lifetime cost each forklift in Victoria pays out to total expenses relating to forklift collision injuries. As a guide, an electronic proximity warning system for a forklift should not exceed $321.8 for economic justification reasons. It should be noted that no consideration to material damage has been given as a result of forklift collisions. This is because it is not possible to obtain a quantitative measure as cases are not fully documented. However, given that nearly every forklift that has been in-service for some while has scratches on the back and/or sides, we know that forklift collisions with general objects occurs often. Finally, no weight has been given to the human cost to individuals, families and communities as a result of collision related forklift injuries.
In short, we recommend that more research should be conducted in developing a practicable electronic forklift proximity warning system that can warn the forklift operator of an impending collision. Success in this area will significantly enhance the hazard management measures currently available in dealing with forklift collisions. The electronic forklift proximity warning system should have a range of at least eight to ten meters given that this is the stopping distance required for a common forklift (with an alert operator) travelling at the upper speed limit of approximately 14 km/h (WorkSafe Victoria, 2005a).

5. Conclusions

This paper analysed forklift injuries and fatalities in the Victorian state of Australia over roughly the past decade. Victoria is considered to be the industrial heartland of Australia and was therefore an appropriate place for a forklift accident analysis. It was shown that there has been a significant reduction in forklift fatalities over the past decade or so within Victorian industry. It was difficult to determine whether total forklift accidents leading to injury decreased during this period as the data was inconclusive. A major finding in this paper was that approximately 50% of forklift accidents leading to injury over roughly the past decade resulted from some sort of collision related incident. It was recommended in this paper that a practicable electronic proximity warning system should be developed to further reinforce existing measures to handle this accident type. The results from our study were compared with a similar study performed by Larsson and Rechnitzer (1994) some two decades ago to see what impacts safety initiatives have had over that time period within Victorian industry. Based on a conservative estimate, we found that there were approximately 400 forklift accidents that led to injury for the time period Larsson and Rechnitzer (1994) analysed (January 1989 to December 1990). When comparing this with the, on average, 100 forklift accidents leading to injury that occurred within Victoria over the past decade or so, we see that there has been a significant improvement that took place in the nineties (some four fold based on a conservative estimate). Larsson and Rechnitzer (1994) found that 15 fatalities occurred throughout the two and a half year period they analysed (October 1987 to April 1990). Considering only two fatalities occurred within Victorian industry from 2010-2012, it is clear that a dramatic improvement has been made to reduce forklift fatalities from occurring. The reduction of forklift injuries and fatalities during the periods analysed by Larsson and Rechnitzer (1994) to modern times are somewhat understated given the expansion of forklift intensive industry and the greater adoption of Just in Time (JIT) manufacturing.

6. Acknowledgements

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7. References