A Framework of Task Demand Factors for Understanding Residential Framing Tasks and Accidents

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Framing contractors consistently have the highest rate of non fatal injuries of all specialty contractors. This case study analyzed 654 safety incidents that occurred over a period of 5½ years in a large residential framing company. Accident analysis and interviews with safety and production experts identified the high-risk tasks, and the task elements that increase the task difficulty and the likelihood of incidents. The study identified the following high risk tasks: (1) Set roof trusses; (2) Install roof sheathing; (3) Snap & cut tails; (4) Brace and block walls; and (5) Lift wall panels. The factors affecting the difficulty of these tasks were analyzed and a framework of task demand factors was developed. The difficulty of residential framing tasks depends on the combination of the following factors: (1) Work platform difficulties, (2) Body posture difficulties; (3) Material/Load handling difficulties, (4) Tool accuracy requirements, and (5) External forces. Measures to reduce the difficulty of tasks are discussed.

Keywords: Framing, Accidents, Safety, Task Demands

Introduction

Framing contractors consistently have the highest rate of non fatal injuries of all specialty contractors (BLS 2008). In 2006, large framing contractors (250-999 employees) showed significantly higher incident rate (13.7) in 2006. Residential framing contractors face additional challenges. In residential construction, OSHA’s Interim Fall Protection Guidelines (OSHA 1999) allow certain trades (including framing contractors) and for certain building height to work above six feet without conventional fall protection (perimeter railing or fall arrest systems). Shah et al (2003) found that residential wood framing workers have one of the highest incident rates in the industry with an average of 45 claims per 100 FTEs (full time employees) per year. This study investigates the work factors that contribute to the high rate of safety incidents among residential framers. This case study analyzes safety incidents to identify the factors that increase the task demands and the likelihood of errors and incidents in residential framing activities, and explores strategies to reduce the task difficulty. Thus, the study has the following objectives:

- To identify the framing tasks with the greatest contribution to safety incidents.
- To identify the task factors that increase the task demands (task difficulty) and consequently the likelihood of incidents.
- To propose safety measures that can reduce the task difficulty.

Previous studies of residential construction accidents has found that falls, struck by and overexertions are the primary hazards in residential framing (Shah et al 2003, Lipscomb et al 2003a, 2003b, 2003c, Lipscomb et al 2008, Dement et al 2003). For specific ergonomic hazards, previous studies identified high risk tasks and suggested ways to reduce exposure. Studies of nailgun injuries identified specific factors affecting the likelihood of accidents, such as worker factors (experience, training), and task factors (awkward positions, and nailgun trigger mechanism). Previous research has not investigated the distribution of incidents to the framing tasks. Also, the investigation of task factors that affect the likelihood of incidents has been very limited.

Methodology

This study analyzes 654 incidents that occurred over a period of 5½ years (January 2003 to June 2008) in a large residential framing contractor. The contractor was selected because he was one of the largest framing contractors in
the state, and agreed to participate in the study and share information regarding the safety incidents. The contractor is a ‘production builder’ (high volume contractor)—the company’s projects are large residential developments with single housing units with one or two floors. The contractor uses ‘alternative fall protection,’ which is typical in residential framing. From 2003-2005 the company employed about 80-90 crews. In early 2008, it employed 40-50 crews. The total labor hours over this period was 5.3 million, and the total workers’ compensation claims cost was $3,046,153. The analysis excluded denied claims and incidents with zero costs.

The incident records provided the following information:
- Date of the incident.
- Injured worker’s length of employment.
- Injured worker’s role (foreman, leadman, carpenter, apprentice or laborer) was provided for 421 incidents.
- Nature of injury and body part(s) affected.
- A brief description of the incident.
- The main activity and task performed were known for 419 incidents.
- Workers’ compensation claim cost.

The incidents were first classified according to the incident event (fall, struck by, etc.). Second, the incidents were classified by the production task that the worker was performing at the time of the incident. Third, the incidents were analyzed to identify the errors and task demand factors that contributed to the incidents. This step involved review of the incident descriptions, and interviews with the safety director, the quality control manager and foremen. The practitioners explained the difficulties involved in the tasks and identified the most common errors related to the incidents.

**Results**

**Incident events**

The 654 incidents were classified under the following ‘Event’ categories:
- **Falls from elevation** include falls to the ground from trusses, roof, ladders, floor deck and other surfaces.
- **Falls at same level** include slips, trips and falls at ground level, truss level and roof.
- **Struck by tool/material/equipment** includes incidents related to power saws (cuts), nailguns, hammers, material handled by the worker, falling objects from other activities, and other sources.
- **Contact with tool/material/equipment** includes incidents due to splinters, cuts from sharp objects (gussets, metal straps), stepping on nails, and debris in eye.
- **Overexertion** includes injuries such as sprains and strains caused during material handling, and bodily reaction that did not involve handling a load.
- **Environment** includes incidents related to heat and insect bites.

Figure 1 illustrates the frequency and claims cost for each incident event. The 91 falls from elevation accounted for 14% of the incidents and 56% of the costs. They had the highest cost per incident ($18,692), and the highest cost incident was $185,450. Falls from trusses (37), falls from roof (24) and falls from ladders (22) were the most frequent falls. Power tool incidents were 21% of total and accounted for 17% of the costs. 43 power saw cuts accounted for 6.6% of the incidents and 13% of the costs. After falls from elevation, sawcuts were the most expensive incident with average cost $9,420. The 89 nailgun incidents were the most frequent event (14% of all incidents) but with low severity ($1,349 per incident, and 4% of total costs). The percentage of nailgun incidents is consistent with previous studies. 72 of the nailgun injuries cost less than $1,000 and only two cost more than $10,000.

In 59 incidents, workers were struck by the materials they were handling—wall panels (27), trusses (7), and other material or equipment (25 incidents handling beams, ladders, generators, etc.). Falling objects from other activities and unsecured components (such as unsecured walls or ladders) were the source of 24 incidents. The 91 overexertion incidents accounted for about 14% of the incidents and 9% of the costs. They included primarily sprains and strains of ankles, knees and lower back. Material handling was the source of 79 incidents: walls and
wall panels (45 incidents, $171,351), trusses (12 incidents, $48,291), and other material (22 incidents, $10,569). 12 incidents did not involve a load—they were related to a movement such as twisting or climbing up/down a ladder, or were attributed to repetitive motion.

![Figure 1: Distribution of incidents by event.](chart)

Trips and slips was 5.1% of all incidents and included falls on ground level (30), falls on trusses (8), roof level (6), one fall on 2nd floor and one on stairs. Eleven incidents involved tripping while carrying heavy material. In seven cases, the workers were walking backwards or stepping down from a ladder. Other incidents involved working on unstable surface (stack of material), stepping on unsecured plywood, or slipping on plywood. In one case, the crane hit the trusses and the worker held on the truss and prevented a fall to the ground. Contact with material or equipment included a large number of incidents (22.5% of total) with low overall cost (4% of total costs), from a variety of sources: Cuts from truss gussets and metal straps, splinters (with one infection which resulted in high cost), stepping on nails, contact with protruding nails while handling material; and debris in eye.

**High risk tasks**

The main activities and tasks performed by the residential framing crews are the following:

- **Site set up.** This activity includes the following tasks: loading / unloading material and equipment; material handling; and cleanup and removing nails.

- **Walls.** The main tasks are the following: (1) Assemble the wall: bottom plate, studs, top plate (2) Install wall shear; (3) Transport wall panels (in case of panelized construction) (4) Lift the walls or panels; (5) Align, plumb the wall and connect to the other walls and slab; (6) Install wall bracing and blocking, and (7) Mark the top plate for truss installation. The walls are typically 8-10’ high, but the crews often have to build ‘specialty walls’, which may be radius walls, or 18’ high walls. A less frequently used method is to install walls panels that have been assembled in the yard.

- **Floors.** In houses with more than one floor, floor installation includes: (1) Breakdown the floor truss package; (2) Material handling to bring the floor trusses to position; (3) Install the floor trusses (set, align and secure); (4) Install the floor decking; and (5) layout the second floor walls.

- **Roof trusses** includes: Break down and sort the roof truss package; Material handling; Set the trusses and install temporary bracing. This activity is typically performed with a crane, but the crews often set smaller trusses by hand, in a process called ‘rolling the trusses.’ Bracing and blocking installs permanent bracing, blocking, rat run etc.; Mark and cut truss tails; and Install fascia.

- **Roof sheathing** includes: Material handling to bring plywood to the roof; install plywood; and mark, cut and cover penetrations.

The incident descriptions, and incident reviews with the safety and quality control directors identified the task that the worker was performing when injured. Figure 2 shows the number and cost of incidents for the various framing
tasks. The claim cost indicates the severity of the incidents during these tasks. The tasks with the highest claim costs are considered to be the high-risk tasks.

Figure 2: Distribution of incidents by task.

Set roof trusses

Setting trusses involved 39 incidents (6% of incidents) for $620.4k (20% of cost). $572.6k (92% of these costs) were due to the 19 falls to the ground. Five incidents involved overexertion, and in four incidents a worker was struck by a truss. Errors leading to falls included: Unsecured or broken components (8 falls). In 2 falls the workers were pulled or pushed off balance. In 2 other falls the workers jumped to avoid being struck by a swinging truss. Loss of balance was the general reason noted in 7 incident descriptions. According to experienced practitioners, overextending is a common error that can lead to such loss of balance.

Roof sheathing

Roof sheathing accounted for 45 incidents (7.3% of incidents) and $328.4k (11% of costs). Falls from elevation was the primary risk—23 falls to lower level accounted for $300.5k. In 5 more incidents, workers fell on the roof (same level). Sawcuts (3 for $12.6k) is another risk factor as the task involves extensive plywood cutting. The main reasons for the falls were the following: Six falls involved a slip or loss of balance while installing the first row of plywood (at the edge of the roof). Six more falls involved tripping or standing on unsecured plywood. Two falls involved slipping on the roof due to the frost and sawdust. In 2 cases, an unexpected force pushed the worker off balance—wind, and a loose nailgun airhose.

Cut truss tails

Cutting truss tails involved 14 incidents (2% of incidents) for $290.9k (10% of cost). The average cost per incident for this task was about $21,000. The task has high risk for falls and sawcuts: the 5 falls accounted for 59% of the costs, and the five 5 sawcuts for 41%. In 3 cases, workers fell when they stepped on the overhanging tails that came off or broke. In three incidents the saw kicked back. In two incidents the worker slipped and contacted the blade.

Brace & block walls

This task involved 69 incidents (10%) for $305k (10% of costs). It included two falls from ladders, seven sawcuts, and 32 nailgun incidents. In six of the seven sawcut incidents, the saw kicked back. In 16 of the 30 nailgun incidents the nail broke through the lumber. In six incidents there was accidental discharge due to tool malfunction, or unintentional firing by the worker. In eight cases, a nail bounced on hard material.
Lift wall panels

Lifting the walls involved 56 incidents for $192,15k: Overexertions (32 for $150k), struck by wall panel (14 for $11.3k). Of the 14 struck by incidents, 9 involved loss of control of the wall. In 4 cases a worker was struck when the wall was set down. These incidents indicate the absence of effective handling points. With regards to overexertions however, loss of control was the cause in only five cases of the 32—the majority of these incidents (27/32) did not involve loss of control.

Discussion: A Framework of Task Demand Factors

The analysis of the incidents identified five major factors affecting the task difficulty. The combination of these factors determines the task demands and the likelihood of errors.

- **Work platform constraints.** Such constraints include the limited support area during truss erection, cutting tails and installing the first row of plywood (top plate and trusses), the slopped and/or slippery roof, and the potentially unsupported trusses or plywood.
- **Ergonomic posture constraints.** Awkward body positions (e.g., bending, extending, turning) increase the task difficulty, contribute to loss of balance, and reduce the accuracy of actions. Awkward body positions contribute to both saw cuts and nail gun injuries.
- **Material/load handling requirements.** The weight and size of the material and other loads handled by the workers influences not only the risk of overexertions, but also the likelihood of other errors, such as loss of balance.
- **Tool use/accuracy requirement.** This requirement indicates the difficulty to use the tool accurately. In cutting board, accuracy is required to control the skill saw and avoid binding and kicking back. Some tasks (such as cutting notches and ripping board) have higher accuracy requirements and smaller error tolerance. Furthermore, different tools have different accuracy requirements, e.g. the different nailgun trigger mechanisms.
- **External forces.** Such forces are external to the worker and out of the worker’s control—they include wind (important in roof tasks), the swinging trusses during truss installation, and other unexpected forces (such as the loose air hose). Coordination problems between workers also generate external forces—e.g., when two workers are lifting a wall and one loses his grip, it creates an external force on the other worker.

The task demand factors are interdependent. For example, work platform constraints may also create difficult ergonomic postures, such as cutting truss tails in awkward positions. The combination of these factors can create a compounding effect in terms of difficulty—for example, installing the first row of plywood has very high task difficulty as the task requires handling large pieces of plywood (load handling), reaching and bending (ergonomic difficulty), and operating a nailgun (tool use), on a very limited work platform (the wall plate and trusses at the edge of the roof). Table 1 assesses the difficulty of the high-risk tasks using a subjective assessment of the five factors. The overall task demand was calculated by multiplying the scores of the five factors.
Table 1

**Assessment of task demands of high risk tasks**

<table>
<thead>
<tr>
<th>Task Demand Factors</th>
<th>Install trusses manually</th>
<th>Install trusses w/ crane</th>
<th>Roof plywood-First row</th>
<th>Roof plywood-roof</th>
<th>Cut tails from roof</th>
<th>Cut tails from ladder</th>
<th>Brace &amp; block walls</th>
<th>Lift walls manually</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work platform</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>2-3</td>
<td>1-3</td>
<td>2-3</td>
</tr>
<tr>
<td>Body posture</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>1-3</td>
<td>4</td>
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<tr>
<td>Load</td>
<td>4</td>
<td>2-3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1-2</td>
<td>4</td>
</tr>
<tr>
<td>Tool accuracy</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>External force</td>
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<td>3-4</td>
<td>2-3</td>
<td>3</td>
<td>2</td>
<td>1-2</td>
<td>1</td>
<td>3-4</td>
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<tr>
<td>Task demand</td>
<td>256</td>
<td>105</td>
<td>360</td>
<td>243</td>
<td>384</td>
<td>180</td>
<td>24</td>
<td>140</td>
</tr>
</tbody>
</table>

1 = Low 2=Moderate 3=High 4=Very High

**Recommendations for Reducing Task Demands**

Reducing task demands is expected to reduce errors and incidents. Reducing task demands is another strategy for accident prevention which is different than reducing exposures or mitigating the consequences of incidents. Measures that reduce the task difficulty can also increase the productivity of the task—as the task becomes easier, workers can work faster and with fewer errors. Thus, in addition to reducing accident costs, they can have productivity improvements that can help justify adoption. Safety measures to reduce the difficulties of the high risk tasks include the following.

**Setting roof trusses**

(1) Provide wider support platform (such as perimeter scaffolding systems). (2) Increase temporary bracing to account for the workers’ loads. (3) Increase the visibility of unstable components (process transparency). (4) Increase control and accuracy of the truss movement during erection.

**Roof sheathing**

(1) Provide wider work platform for the first row of plywood. (2) Prevent installation of unsecured plywood: through training in work practices that reduce ‘landmines, and/or by developing error-proofing mechanisms that make it impossible for a component to be installed without being adequately secured. (3) Increase the visibility of unsecured components.

**Cut tails**

The use of perimeter scaffold can provide easy access, reduce the ergonomic difficulties and increase the productivity of the task.

**Block and brace walls**

(1) Improve tools—e.g., develop automatic shutoffs on power saws (when the saw kicks back), develop power saws that are more difficult to bind. (2) Provide better access to the work face or preassemble difficult to access
components; (3) Increase the new workers’ skill through training in performing difficult cuts and training regarding the correct hand position during nailing.

Lift wall panels

When mechanical means are not available, the following measures can reduce task difficulty: (1) Divide long walls in smaller assemblies; (2) Provide guidelines regarding what manpower is needed for different situations; (3) Provide pick points and handles; and (4) Plan the work (layout, path) to reduce the distance and provide clear path.

Perimeter scaffolds (traditional and ‘bracket scaffolds’) reduce the difficulty of several high risk tasks—setting trusses, cutting tails, installing fascia, and roof sheathing first row, and reduce ergonomic posture difficulties. The contractor has evaluated different scaffolding systems, but has not adopted them because of cost considerations—the additional cost would exceed the safety savings, and the effect on the profit margin would be considerable. With regards to fall protection, the contractor believed that the strongest force for adoption would be if the developers require the use of fall protection systems, so that the adopters do not have a cost disadvantage. However, the contractors cost evaluations have not accounted for the productivity increases on the affected operations. A better understanding of the effect on productivity would facilitate the use of these measures.

In addition to reducing task demands, contractors also need to increase the workers’ ability to successfully cope with such demands. This requires training the less experienced workers in techniques and procedures for difficult cuts, roof work, and other high demand tasks.

Conclusions

This study analyzed 654 safety incidents that occurred over a period of 5½ years in a large residential framing company. The analysis of the accidents identified the high-risk tasks, and the task elements that increase the task difficulty and the likelihood of incidents. The study identified five primary task demand factors: (1) Work platform difficulties, (2) Body posture difficulties; (3) Material/Load handling difficulties, (4) Tool accuracy requirements, and (5) External forces. The combination of these factors generate the difficulty of residential framing tasks. Based on the findings, the paper proposed measures to reduce the task demands of the high risk tasks.

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References


