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An Empirical Examination of the Relationship between Lean Construction and Safety in the Industrialized Housing Industry

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Abstract

Proponents of Lean production claim that the implementation of Lean principles reduces accident rates. However, currently there is no empirical evidence in construction, in particular industrialized housing, on this hypothetical relationship. Current industry practice shows impressive results from using Lean tools in modular home manufacturing, yet its impact in employee safety outcomes is less understood. To explore this issue, this paper discusses the potential impacts of a specific concept used in Lean, continuous improvement (CI), on safety outcomes and shows results of an empirical analysis from an industry-wide survey of industrialized homebuilders on safety outcomes and CI programs. The analysis focused on 67 of 141 responses from builders in the U.S. that provided information on the use of CI programs. Nearly half of the survey respondents (62 homebuilders) use CI programs. The analysis showed that the presence of CI programs is associated with significantly lower injury incidence rates as compared to builders without CI programs. However, the presence or absence of CI programs did not result in significant differences in total OSHA-recordable cases, cases with restricted or transferred employees, total days lost, and days with restriction or transfer.

Findings from this research will contribute to a better understanding of the applicability and potential benefits of Lean in the housing industry in terms of employee safety outcomes. Specific Lean strategies (CI programs) do appear to have some positive effects on OSHA incidence rates, which suggest that Lean may be beneficial not only for process improvement and waste reduction, but also for improving safety in the construction industry.

Keywords: homebuilders, safety, incidence rate, continuous improvement programs, Lean construction

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Introduction and Background

U.S. Industrialized Housing

In 2007, approximately 5% of all newly built single family homes in the United States were factory-built (U.S. Census Bureau 2007). Industrialized housing includes many types of structures built in the factory either as panels (e.g. panelized or pre-cut homes) or units (e.g. HUD code homes and modular homes). The U.S. Department of Housing and Urban Development (HUD) provides a federal building code for constructing HUD code homes (HUD 2006), whereas a modular home is built to local building codes similar to site built homes (e.g. stick build). Both HUD code and modular homebuilders use three dimensional sections or modules that are typically 95% finished when they leave the factory (Carlson 1991). Once modules are finished at the plant, they are transported on a flat bed truck to the construction site. At the construction site, modules are lifted by crane and assembled on a permanent foundation. The resulting home meets conventional code and zoning requirements and in particular modular homes are typically indistinguishable from nearby conventional site-built housing (Mullens 2004). This paper concentrates on manufacturers that produce full units rather than panels, and data collected from the survey focuses on responses from individual plants and not the onsite set-up crews.

Although industrialized housing relocates many of the field operations to a more controlled factory environment, the construction techniques share many similarities with those employed in traditional site homebuilding, including construction methods, materials and equipments. Regarding the production method, Mullens (2004) indentifies two main differences between industrialized and site-built housing construction: 1) industrialized housing takes place inside a factory on a moving line, and 2) construction crews within industrialized housing plants are a dedicated resource and the "parade of trades" (Tommelein 1999, p. 304) happens quickly. Further, Mullens (2004) argues that these manufacturers still "stick build under a roof" failing to take advantage of modern manufacturing technologies that can drive vastly improvement on quality, cycle time and productivity. Therefore, industrialized housing methods can be compared reasonably to other current construction methods and research.

The U.S. construction industry is characterized by low productivity, overruns in cost and schedule, errors, poor reputation, shortage of skilled labor and poor safety. In particular, lack of safety is one of the chronic problems in construction, as is evident from the high accident rates. Employees in the industrialized housing industry sustain higher rates of reported injuries than their counterparts in the on-site construction industry. In the United States, total injury and illness incidence rates for prefabricated wood manufacturing ranged from 9.5 to 14.3 per 100 workers over the past 5 years, while the residential construction incidence rate is approximately 5 per 100 workers (Bureau of Labor Statistics 2008). Injury rates for both sectors are higher than the national average, 4.2 injuries per 100 workers, which justifies an increased focus on improving safety in all facets of residential construction, whether in industrialized housing plants or in conventional housing onsite.

Lean production is a popular strategy in manufacturing that is being applied to the construction industry (Koskela 1993) and the use of Lean-based tools like Last Planner (LP) (Ballard and Howell 1994) claims to reduce accident rates: crews that used Lean

Construction tools, including LP, had about 45% lower accident rate than crews in the same company, performing similar work, who did not use the LP system (Thomassen 2003). The implementation of Lean concepts and techniques encourages less material in the work area, an orderly and clean workplace, and systematic work flow. Indeed, standardizing, systematizing and regularizing production can be expected to lead to better safety as a side effect (Kobayashi 1990). This can be accomplished using the First Run Studies, another Lean tool. First run studies implemented through a PDCA (plan, do, check and act) cycle can be used to redesign critical activities as an integral part of a continuous improvement effort (Salem et al. 2005; Abdelhamid and Salem 2005). Initial results from early industry practice shows that the use of Lean tools has great potential to boost the efficiency and quality of industrialized homebuilding operations (Dentz and Blanford 2007). Although Lean as a production approach for industrialized homebuilders is in its early stages, the Manufactured Housing Research Alliance (MHRA) and HUD's Partnership for Advancing Technology in Housing (PATH) have helped the industrialized housing industry implement Lean with impressive results. During 2006, MHRA supported and guided nine industrialized housing plants to incorporate Lean production methods in their operations (Dentz and Blanford 2007). These Lean implementations resulted in significant waste reduction (e.g. 12% production space reduction, 10% raw material damage reduction, and 28% labor reduction) (MHRA 2007).

The Influence of Lean on Safety

Safety has historically been treated as a separate subject, which could be improved in isolation from production. However, safety is an integral part of every production process, not an afterthought or an add-in, because safety depends on every action, material, and person used. Work processes are inherently safe or hazardous according to the safety hazards present in each step required to complete a process. Safety performance depends on the nature of the job and must be continuously maintained and improved as part of those processes (Koskela 1992). By carefully planning processes to minimize safety risks, work can be less hazardous.

In Lean terminology, poor safety is a form of waste. Injuries are costly not only in terms of human suffering but also in terms of worker compensation costs, lost time, lost productivity, and higher employee turnover. Therefore, it is imperative to incorporate safety into process and production plans, in order to achieve projected goals of improved worker health, reduced costs, and increased value. Initial efforts of Lean implementation in the industrialized homebuilding industry show this integration by adding a sixth S, to the Lean tool 5S, for safety by conducting a process improvement event in the continuous improvement process dedicated to safety (MHRA 2007).

There are few guidelines on how to combine Lean principles with safety initiatives in the workplace (Mitropoulos et al. 2007). In response to the lack of guidance, two possible scenarios are proposed for explaining how Lean production practices may affect safety (Figure 1) through the use of continuous improvement (CI) programs.

1. CI programs will reduce opportunities for accidents through reduced waste (in materials, motions, and process steps) and therefore reduced safety hazards.
2. CI programs can include safety initiatives as one category of improvement projects undertaken.

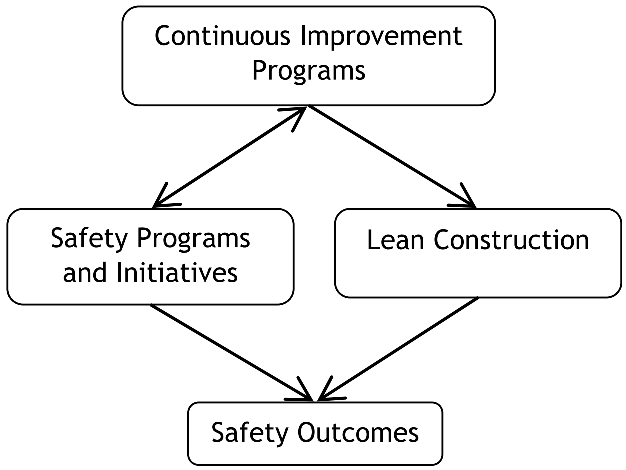

Figure 1. Proposed influence of safety programs and initiatives and continuous improvement programs on safety outcomes.

In the first scenario, the conscious effort toward continuous improvement through the reduction of waste in materials and processes may result in reduced opportunities for accidents. The inherent practice of continuous improvement drives safety improvements without the explicit integration of specific safety programs. In Figure 1, the pathway to safety outcomes from CI programs passes only through Lean construction. In practice, construction projects with best safety performances are likely to use good scheduling and housekeeping practices, which are main tenets of Lean production (Veteto 1994, Mattila et al. 1994). Using two principles of Lean, reducing waste and increasing efficiency, often result in a reduction of process steps, materials used, and motions required. These reductions in turn will reduce the probability of incurring an accident or coming in contact with hazardous materials. Reducing materials and time to completion will decrease exposure to hazardous chemicals, excessive noise, biomechanical hazards, and other industrial hygiene hazards. For example, by reducing the number of times a heavy object is lifted and handled, the total time needed to complete a process is reduced (improved efficiency) and the risk of back injury is also reduced. Improved housekeeping (e.g. 5S and visual management), which is another tenet of Lean production, will also reduce hazards such as chemical exposures and tripping/falling hazards.

The second scenario involves safety programs becoming a part of Lean practices. Safety programs can be integrated with Lean through incorporation in CI programs. Following Figure 1 as a guide, safety outcomes are realized from CI programs through the interaction with safety programs and initiatives. In construction, the working environment constantly changes among projects, so safety performance is ultimately dependent on the avoidance of unsafe acts by workers (Nishigaki et al. 1992). This finding stresses the importance of having all employees involved in safety planning. Lean production practitioners often include opportunities for team work and continuous improvement in normal operations. Allowing safety to be considered an aspect of team work projects and continuous improvement efforts allows employees and managers to discuss and reduce safety hazards as part of continuous improvement opportunities.

Decisions regarding the elimination and control of safety hazards can be incorporated into Lean planning activities such as kaizen events. The common approach for addressing safety hazards in the workplace follows the National Safety Council's Hierarchy of Controls (National Safety Council Study 1950). The first step is to determine if the hazard can be eliminated completely or if it must be controlled. If the hazard cannot be eliminated, the second step is to determine how the hazard can be controlled: through engineering controls, administrative changes, personal protective equipment (PPE), or some combination of these three alternatives. Engineering controls are widely considered the most effective, although often most costly, method of control while PPE are considered the least effective (Friend and Kohn 2007). In reality, PPE are often used in conjunction with engineering and administrative controls when these preferred methods cannot reduce the hazard to an acceptable level. Lean processes may automatically address many safety hazards from the elimination (through reducing steps, exposures, etc.) and engineering control perspectives through process designs. The critical evaluation of processes that occur through Lean will also benefit safety if safety concerns are incorporated as part of the evaluation process. Any concerns identified that cannot be completely resolved through process design will then become candidates for administrative or PPE controls, which may also be considered through continuous improvement activities.

Integrating Safety and Lean Construction

One of the focuses of Lean Construction is the creation of a culture within the company of continuous improvement. Diekmann et al. (2005) identified five major Lean principles applicable in the housing industry: customer focus, culture/people, workplace standardization, waste elimination and continuous improvement/built-in quality. Furthermore, Diekmann et al. (2005) suggested that CI programs can be used as a guide for creating a construction organization that moves closer to the ideal of Lean production. Koskela (1993) concluded that the implementation of Lean production concepts into construction seems to be a major factor in the endeavor to eliminate accidents. Koskela identified strategies to improve construction safety through the use of Lean production concepts: 1. designing, controlling and improving engineering and construction processes to ensure predictable material and work flow on site, 2. improving safety management and planning processes themselves to systematically consider hazards and their countermeasures, and 3. improving safety related behaviors- instituting procedures that aim at minimizing unsafe acts.

Lean principles may be used to support safety programs in industrialized housing manufacturers by increasing safe behavior (and thereby reducing injury rates), and safety in turn can be integrated into Lean processes. However, the proposed benefit of improved safety through the use of Lean production (Saurin et al. 2006, Koskela 1992, 2000) has not been measured empirically. Therefore, the purpose of this research is to determine if the use of Lean Construction principles, specifically the use of CI programs, is associated with improved safety metrics in the industrialized housing industry.

In this paper, continuous improvement is the focus of analysis, theorizing that CI programs are one key element of Lean Construction as Diekmann et al. (2005) suggest. Industrialized homebuilders that use any type of CI programs are exhibiting the initial foundation for developing a Lean culture. As such, current successes in production and safety should be investigated and disseminated to encourage the development of a full Lean Construction program. Due to the potential influence of Lean processes on safety outcomes, we hypothesize that builders using the Lean component of continuous improvement will have improved safety, as measured by fewer OSHA-recordable accidents and fewer cases with days away from work, restricted, or transferred.

Research Design and Method

The goal of this analysis was to determine the prevalence of Lean practices, as measured by CI programs adoption currently being used by U.S. homebuilders, and the impact of these practices on safety performance and employee satisfaction. The data was gathered through a large scale survey of industrialized homebuilders, primarily HUD-code and modular manufacturers (MHRA 2007). The target population for the survey was 150 industrialized homebuilders across the U.S. Together, they operate 275 plants, both modular and HUD Code. Surveys were distributed to a key decision maker at each company, usually the president or CEO. Surveys were distributed and results gathered during a four-month period from January to April of 2005. 141 plants completed the survey, representing 51% of the 275 operating plants initially contacted. Participants recorded their answers for each survey question in a spreadsheet. If a participant left any question unanswered, that plant was not included in the analysis that pertained to the blank answer.

The original survey included five major sections of metrics: product characteristics, plant characteristics and operational performance, safety/employee satisfaction and quality/customer satisfaction. This paper focuses on the following eight items regarding safety.

Q1. How many OSHA Recordable Accidents have been reported in the last 12 months?

Q2. How many of these cases resulted in days away from work?

Q3. How many of these cases resulted in job transfer or restriction (light duty)?

Q4. How many total work days were lost in accident-related days away from work?

Q5. How many work days were affected by accident-related job transfers or restrictions (light duty)?

Q6. What was the average % absenteeism in the last year?

Q7. What was the % production labor turnover in the last year?

Q8. List any continuous improvement programs that were used in the last year. For example, quality councils, quality circles, continuous improvement teams, etc.

In this paper and throughout the survey analysis, accidents are defined as OSHA recordable incidents (OSHA 2007) and all accidents are treated equally regardless of severity. Responses for Q1 to Q7 were in a quantitative form (e.g. number of cases, number of days or percentages); whereas responses for Q8 were qualitative in nature. The latter question was coded with 1 and 0, either that the builder had an active program (e.g. continuous improvement and/or incentive program) or not, respectively. Thus, there are two levels of Lean construction practices (e.g. active and none), as measured by CI programs adoption provided in Q8.

The data analysis had two major sections: 1) Descriptive characteristics comparing the two levels of continuous improvement practices; and 2) Analysis of the Hypotheses to identify statistical significance between various safety outcomes and Lean production, as measured by CI programs adoption and OSHA recordable statistics. Before testing the hypotheses, a normality test (Shapiro-Wilk, $a = .05$) was conducted to check the distribution of the data. Results from the normality test revealed sufficient information to reject the null hypothesis ($p = .00$). Since the data were not normally distributed, nonparametric statistical techniques were used. The Mann-Whitney Test was used, which is similar to an independent t-test for nonparametric data. This analysis helps to identify differences between groups (no CI program versus active CI programs) across the safety metrics, by testing the null hypothesis that there is not a significant difference among the groups ($p < .05$). Builders using CI programs were predicted to have lower total incidents and incidents with days away, restricted, or transferred, lower incidence rates, and lower days away or restricted or transferred.

The null hypothesis is stated as follows:

> H_o: *There is no difference in safety outcomes between builders who practice Lean, as measured by CI programs adoption, and those builders that do not use CI programs.*

The five alternate hypotheses are stated as follows regarding builders using CI programs, as a component of Lean construction, practices:

> H_a: *OSHA-recordable incidents will not be equal to those builders not using CI programs.*
>
> H_b: *OSHA-recordable accidents resulting in days restricted or transferred (light duty) will not be equal to those builders not using CI programs.*
>
> H_c: *Total recordable incidence rates (TRIR, per 100 workers) will not be equal to those builders not using CI programs.*
>
> H_d: *Total days lost will not be equal to those builders not using CI programs.*
>
> H_e: *Days restricted or transferred (light duty) will not be equal to those builders not using CI programs.*

Results

The presentation of the results from the survey of industrialized homebuilders is grouped into two major sections, as follows: 1) Descriptive characteristics including basic statistics of the survey, and 2) Analysis of the Hypotheses.

Descriptive Statistics

Of the 141 plants that completed the survey, 62 (44%) reported an active CI program. A summary of participating plant operating characteristics which answered Q8 on CI programs is shown in Table 1. Only the 67 builders responding to Q8 are included in subsequent analyses. Furthermore, since the sample size of the plants without an active CI program was small relative to the sample size from the plant with an active CI program, a reduced sample of the plants with active CI programs was drawn to match the range for number of homes produced per year of the "no active CI program" group. The metric of number of homes produced per year was used because it describes the physical product that flows through and is produced by participating plants. It suggests the overall scale and pace of the operation. The annual production of plants without a CI program ranged from 194 to 502 homes. Out of the 62 plants with active CI programs, 16 plants fell into this range.

Table 1. Summary of Mean (SD) Operating Characteristics

Homebuilder Operating Characteristics	Active CI Program (n = 62)	Active CI Program, Reduced Sample (n = 16)	No Active CI Program (n = 5)
Annual Sales ($M)	30.9 (20.4)	21.8 (5.76)	17.2 (3.95)
Modules produced per year	1343 (1031)	833 (190)	645 (150)
Homes produced per year	677 (561)	358 (105)	344 (145)
Plant size (ft^2)	133,528 (77,498)	142,729 (90,140)	126,276 (36,180)
Annual number of OSHA-recordable cases (per 100 workers)	16.4 (11.2)	11 (9.4)	31.4 (26.7)
Annual cases with days away from work (per 100 workers)	4.1 (4.7)	2.8 (2.6)	9.8 (8.5)
Annual cases with job transfer or restriction (per 100 workers)	10.8 (35.6)	7.88 (6.79)	11.9 (11.6)
Total recordable incidence rate (per 100 workers)	14.5 (9.75)	9.96 (8.27)	34.7 (19.6)
Days lost in accident-related cases per year (per 100 workers)	70.7 (90.5)	61.6 (121)	99.5 (82.4)
Days affected by case-related job transfers or restrictions per year (per 100 workers)	121 (201)	85.2 (92.6)	176 (171)
Annual absenteeism	6.95% (11.5%)	5.21% (2.82%)	7.64% (4.47%)
Annual labor turnover	56.2% (39.6%)	47.8% (42.7%)	53.6% (53.6%)

From the results of the Mann-Whitney test, no significant differences between the levels of Lean construction practices were found for homes produced per year (p =.088), plant size (p = .808), absenteeism levels (p = .169), and labor turnover (p =.638) when using the full sample. However, builders with active Lean programs (full sample, n = 62) were significantly larger than those without Lean programs in terms of annual sales (p =.047) and modules produced per year (p =.024).

Analysis of the Hypotheses

The hypotheses testing was performed for the full sample (plants with CI programs, n = 62) and then on the reduced sample (plants with CI programs, same range of number of homes produced as plants without CI programs, n = 16).

Results from the Mann-Whitney analysis showed significant differences between builders that do or do not have an active CI program for total incidence rate per 100 workers (full sample p = .029, reduced sample p = .011). Therefore, there is sufficient information to declare that the number of accidents per workers differ between those builders that use Lean practices (through an active CI program) and those that do not, which is H_c. Builders using CI programs had lower incidence rates than those without CI programs. Both samples approached significance (full sample p = .075, reduced sample p = .109) for having fewer recordable accidents per year than the plants with no CI program (H_a), while the remaining safety metrics were not significantly different between the two groups ($p \geq .179$). Therefore, the other hypotheses (H_b, H_d, and H_e) could not be supported, which means that significant differences were not found for total cases, cases with days restricted or transferred, total days lost, and total days restricted or transferred.

Discussion and Conclusions

This analysis was conducted to see if there was a relationship between builders that use CI programs (an important component of Lean) and safety outcomes, as measured by OSHA recordable incidents and days away, restricted, or transferred. Incidence rates were significantly lower among builders with a CI program. While this finding suggests that builders incorporating parts of Lean practices have safer workplaces than those without, the other results were inconclusive for total cases, light duty cases, total days lost, and days restricted or transferred. The incidence rate for builders with active Lean programs (14.5 per 100 workers) is similar to reported rates for prefabricated wood building manufacturing (9.5 per 100 workers in 2007) (Bureau of Labor Statistics 2008). However, the incidence rate for builders without a Lean program was much higher at 34.7. Unfortunately, all of these rates were much higher than rates for manufacturing overall (5.6), residential construction (4.8), and overall industry (4.2) (Bureau of Labor Statistics 2008). These rates imply that while CI programs may be making a significant difference in the safety of industrialized home builders, there is still a huge need for safety improvements in this sector, which perhaps can be realized through full Lean implementation.

The current results do provide some support for the prediction that accident rates will be reduced with the implementation of Lean. Based on the data and statistical analysis, it appears that CI programs are associated with significantly improved (lower) incidence rates regardless of plant production volumes. Homebuilders using CI programs had incidence rates that were 58% lower than those without active CI programs, which support the theory that safety improves with the use of at least one Lean process (continuous improvement). The reduction in incidence rate in homebuilders with CI programs was supported when comparing both samples (the entire sample spanning a wide range of production volume and the sample that more closely matched the production volume of the respondents with no CI program). By comparing homebuilders with similar production levels, the chance that safety records improved with size (e.g. more resources available to improve safety in larger companies) was addressed. Also, absenteeism and labor turnover rates were not significantly different between the groups, which suggest that safety was not influenced by the number of new hires or lack of personnel due to absences.

The present study supports the results from another study of Lean Construction in which Thomassen et al. (2003) found that both the incidence rate for days away cases and absenteeism was lower for workers (although not reaching statistical significance) on projects using Lean Construction compared to projects not using Lean processes. It should be noted that none of the Lean Construction methods used in the Thomassen et al. study focused directly on safety; instead, it appears that safety improvements were an effect of improved planning and methods.

Another interesting finding from the survey results was that the incidence rate was significantly lower among builders with CI programs, but the days away were not significantly different from builders with no active CI program. This could mean that the number of severe cases resulting in days away, restricted, or transferred were not reduced as a result of CI programs, but more minor recordable cases were avoided. Minor accidents may have been reduced through CI programs such as improved housekeeping, which could reduce trip/slip/fall hazards. These results also suggest that Lean practices may need to be used in conjunction with formalized safety programs to significantly reduce more severe cases. Although there was no data collected regarding the length of time CI programs had been in place for each builder, it is possible that with time, formalized safety programs may be integrated into Lean programs as a part of process improvement initiatives.

Some limitations to the study results must be noted. The industry wide survey included more plants that were primarily HUD code rather than modular. It is likely that some modular manufacturers chose not to participate because they do not wish to be associated with the manufactured housing industry. The findings that emerged from this study are limited to associations between continuous improvement, as an important element of Lean, and safety and not causal effects. The current survey did not explore any Lean tools other than CI programs, so future surveys could gain a more complete understanding of the use of Lean in industrialized housing by including more questions on the specific Lean tools being used. Several directions of future research might build on the findings of this study by answering two fundamental research questions: 1. Does the implementation of Lean principles result in improved safety? and 2. Can Lean and safety principles be combined to develop a framework for improving processes and safety simultaneously? For instance, Thomassen et al. (2003) has already reported successful reduction of incidence rates by 45% by using other Lean Construction tools such as Last Planner (LP) and other planning tools. The incorporation of other Lean Construction tools such as 6S and LP should be studied from the perspective of safety improvements in the industrialized housing industry to determine if a more complete implementation of Lean Construction results in further safety improvements beyond those found with CI programs. If these results do find links between safety and Lean Construction, a model of how to incorporate safety initiatives into a culture of Lean will be highly valuable to management and will strengthen the case for using Lean Construction.

The analysis and discussion presented in this paper provides theoretical and empirical reasoning for the link between CI programs and improved safety outcomes. Safety may be improved through Lean processes and through the opportunity to include safety in process improvement projects, and the analysis of survey results shows that homebuilders with active CI programs have better safety statistics than homebuilders that do not actively use a CI program. Therefore, a full implementation of Lean in the industrialized housing industry may further improve processes in terms of both efficiency and safety.

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References

Abdelhamid, T. and Salem, S. (2005). "Lean Construction: A New Paradigm for Managing Construction Projects". International Workshop on Innovations in Materials and Design of Civil Infrastructure, December 28-29, 2005, Cairo, Egypt.

Ballard, G. and Howell, G. (1994). "Implementing Lean Construction: Stabilizing Work Flow." Proceedings of the 2nd Annual Meeting of the International Group for Lean Construction, Santiago, Chile.

Bureau of Labor Statistics. (2008). Industry Injury and Illness Data. Retrieved November 21, 2008 from http://www.bls.gov/iif/oshsum.htm#03Summary%20Tables

Carlson, D. (ed.) (1991). Automated Builder: Dictionary/Encyclopedia of Industrialized Housing, Automated Builder Magazine, Publications Division, CMN Associates, Inc., Carpinteria, CA.

Dentz, J. and Blanford, M. (2007, July). "Lean Factories Cut Costs, Boost Production". Automated Builder.

Diekmann, J. E., Krewedl, M., Balonick, J., Stewart, T. and Wonis, S. (2004/2005). "Application of Lean Manufacturing Principles to Construction", CII report #191, Review obtained from Lean Construction Journal, 2005, 2(2), 51-54.

Friend, M. A. and Kohn, J. P. (2007). Fundamentals of Occupational Safety and Health (4th ed.) The Scarecrow Press, Lanham, MD. 477p.

Kobayashi, I. (1990). 20 Keys to Workplace Improvement. Productivity Press, Cambridge, MA. 264p.

Koskela, L. (1992). Application of the New Production Philosophy to Construction. Technical Report #72. Center for Integrated Facility Engineering. Department of Civil Engineering. Stanford University. 75p.

Koskela, L. (1993). "Lean production in construction". Proceedings of the 10th ISARC, Houston, Texas, May 24-26, 47-54.

Koskela, L. (2000). "An Exploration Towards a Production Theory and its Application to Construction". Ph.D. Dissertation, VTT Publications 408. VTT: Espoo, Finland, 296 pp.

Manufactured Housing Research Alliance. (2007, July). Pilot Study: Applying Lean to Factory Homebuilding. U.S. Department of Housing and Urban Development, Office of Policy Development and Research, Washington, D.C., July 2007.

Mattila, M. , Ranteanen, E. and Hyttinen, M. (1994). "Quality of work environment, supervision and safety in building construction". Safety Science, 17(4) 257-268.

Mitropoulos, P., Cupido, G., & Namboodiri, M. (2007). "Safety as an emergent property of the production system: How lean practices reduce the likelihood of accidents". Proceedings IGLC-15. Michigan,USA.

Mullens, M. (2004). "Production flow and shop floor control: Structuring the modular factory for custom homebuilding" Proceedings of the NSF Housing Research Agenda Workshop, Feb. 12-14, 2004, Orlando, FL. Eds. Syal, M., Mullens, M. and Hastak, M. Vol 2.

National Safety Council Study. (1950). "Hierarchy of Controls." Retrieved July 15, 2008 from http://www.dupontsafetyrevealed.org/DupontSTOP/STOP/EvolutionofSTOP.htm

Nishigaki, S., Vavrin, J., Kano, N., Haga, T., Kunz, J. and Law, K. (1992). Humanware, Human Error, and Hiyari-Hat: a Causal-chain of Effects and a Template of Unsafe Symptoms. Center for Integrated Facility Engineering, Stanford University. Technical Report No. 71. 22p.

Occupational Safety and Health Administration (OSHA). (2007). Recording and Reporting Occupational Injuries and Illnesses. 29 CFR Part 1904 (2nd edition).

Salem, O., Solomon, J., Genaidy, A., and M. Luegring (2005). “Site Implementation and Assessment of Lean Construction Techniques”. Lean Construction Journal, 2(2) 1-21.

Saurin, T.A., Formoso, C.T., Cambraia, F.B. (2006). “Towards a common language between Lean production and safety management.” Proc. Fourteenth Annual Conference of the International Group for Lean Construction (IGLC-14), Santiago, Chile.

Thomassen, M. A., Sander D., Barnes K. A., Nielsen A. 2003. “Experience and results from implementing Lean construction in a large danish contracting firm.” Proceedings of 11th Annual Conference on Lean Construction, pp.644-655, July 22-24, Blacksburg, VA.

Tommelein, I., Riley, D., and Howell G. (1999). “Parade game: Impact of work flow variability on trade performance.” Journal of Construction Engineering and Management, ASCE, 125(5) 304-310.

US Census Bureau (2007) Type of Construction Method of New One-Family Houses Completed. http://www.census.gov/const/C25Ann/sftotalconstmethod.pdf

US Department of Housing and Urban Development (2006). Manufactured Home Construction and Safety Standards, 24 CFR Part 3280, Washington, DC.

Veteto, C. (1994). “The relationship between planning and safety”. Cost Engineering, 36(4) 23-26.