Damaj, O., Fakhreddine, M., Lahoud, M., Hamzeh, F. (2016) Implementing Ergonomics in Construction to Improve Work Performance. ." In: *Proc. 24th Ann. Conf. of the Int'l. Group for Lean Construction*, Boston, MA, USA, sect.11 pp. 53-62, Available at: <www.iglc.net>

IMPLEMENTING ERGONOMICS IN CONSTRUCTION TO IMPROVE WORK PERFORMANCE

Omar Damaj[1], Mohamad Fakhreddine[2], Makram Lahoud[3], and Farook Hamzeh[4]

ABSTRACT

Traditional construction projects suffer from several productivity-related problems that result in delays and cost overruns; consequently, projects often fall short of owner set goals. The need for investigations into the causes of these inefficiencies is crucial as poor work conditions reduce the quality and efficiency of work processes. Ergonomics, defined as the study and optimization of workers' efficiency in their work environment, brings about safety and productivity improvements through an enhancement of work conditions. However, Ergonomics has not been applied in the Middle East and specifically in Lebanon. Moreover, very little research has been performed on ergonomics planning in this region with a booming construction industry despite the pressing need to modify tools and tasks to fit workers' needs. Data from field surveys and site visits from several construction sites were analyzed to assess the use of ergonomics. Despite the positive impacts that ergonomics planning can provide, contractors are reluctant to change and are held back by cultural and social barriers. The study highlights numerous difficulties faced on construction sites, analyzes the barriers that are preventing ergonomics from being implemented in Lebanon, and discusses potential solutions. This study can be used as basis for possible future implementation plans and further studies focusing on ergonomics in Lebanon and the Middle East.

KEYWORDS

Lean construction, Safety, Visual Management, Ergonomics, Lebanon.

[1] Civil Engineering Student, Civil and Environmental Engineering Department, American University of Beirut, Lebanon, +9613662187, omd05@mail.aub.edu

[2] Civil Engineering Student, Civil and Environmental Engineering Department, American University of Beirut, Lebanon, +9613903734, mhf13@mail.aub.edu

[3] Civil Engineering Student, Civil and Environmental Engineering Department, American University of Beirut, Lebanon, +96170146175, mfl03@mail.aub.edu

[4] Professor, Civil and Environmental Engineering Department, American University of Beirut, Lebanon, fh35@aub.edu.lb

INTRODUCTION

The lean philosophy revolves around the respect and appreciation of all individuals involved in the production process. Ergonomics originates from the Greek *ergon* (work) and *nomos* (laws), it is the science of analyzing work and subsequently designing; the process, equipment, tools, and methods to fit the physical, intellectual and skill-set of workers. Applying ergonomics has been shown to reduce costs associated with work-related injuries and increase value creation through an improvement in overall worker productivity and morale (Geng, 2004). Construction sites in Lebanon are known for deplorable work conditions, there is a considerable need to improve the construction environment.

In the early days of industrialization, getting the job done was more important than the well-being of the employee. Around the 1940s, it was observed that the work could be done more efficiently if the equipment was easier and safer to use; the science of ergonomics was born (Jazani & Mousavi, 2014). Construction labourers are at high risk of work related injuries due to physically demanding tasks that include working in awkward positions, lifting heavy materials, handling irregular loads, bending and twisting the body, working above shoulder height, working below knee level, and pushing and pulling (Smallwood & Ajayi, 2006). As a result, workers' performance becomes unpredictable and creates variability. The lean approach to improve production rate focuses on reducing variability in output, and work related injuries must be controlled through ergonomic planning (Thomas, Horman, de Souza, & Zavřski, 2002). Poor labour productivity on construction sites is a major contributor to delays. The reduction in productivity and increased worker absenteeism as caused by poorly designed work processes brings about; unexpected scheduling changes (Inyang, Al-Hussein, El-Rich, & Al-Jibouri, 2013). Work processes need to be modified in order to mitigate the negative impacts created by the present poor conditions on construction sites; also, activities and tasks could be tailored to accommodate workers in a way that minimizes physical discomfort.

At first sight, ergonomic planning seems to increase costs due to the need for; employee training and investment in supportive equipment. However, these are short run costs that could and contribute to a reduction in the overall cost of the project, in the same manner as a lower insurance premium does, since contractors who provide a safe working environment benefit from lower insurance rates (Inyang et al., 2013).

Injury related costs are also an important aspect to consider; worker absenteeism is considered waste and leads to suboptimal output. Engineers at the department of construction management at Nelson Mandela Metropolitan University studied how the design is conducted; they found that designers do not understand material characteristics such as weight, density etc. and lack the knowledge that needs to be injected into the design of work processes. Further, the study reported that designers do not give enough attention to construction site ergonomics, and the work tasks are developed independently of the labor force that is going to perform the work. (Smallwood, 2012).

In Lebanon, work conditions for construction workers are not necessarily conducive for safe and efficient production. Workers are often seen working on high heights with no scaffolding, bending in awkward positions, and lacking the necessary safety gear.

Nonetheless, improvements are attainable through minor modifications. The objective of this paper is to assess the application of ergonomics in the Lebanese construction industry.

METHODOLOGY

To put theory in practice, two Lebanese sites will be analyzed. The construction work will be monitored closely; identifying opportunities to make tasks smoother and workers more productive. The study aims at finding potential modifications that could improve the work conditions. The authors will have the opportunity to propose solutions and the potential benefits they produce. Interviews with site workers will be done in order to gather information regarding task details, safety measurements, crew productivities, problems encountered, and activities that could be improved. Furthermore, the study will examine the impacts of implementing ergonomics on work productivity, safety, worker morale, and employee comfort. Findings will be discussed and analyzed, displaying what is to be gained by introducing ergonomics to the construction industry in Lebanon.

ADVANTAGES OF ERGONOMICS

Within the workplace, ergonomics focuses on the prevention of injuries and the improvement of workers' efficiency through all phases of construction (Hwaiyu Geng, 2004). The main benefits of ergonomics are listed below.

Reduction in costs: Reducing costs associated with work-related injuries which might have high medical expenses. Insurance companies charge lower rates for contractors with low documented injuries. Hence, increased profits can be attained through decreased costs and earlier finish. (Hwaiyu Geng, 2004).

Higher productivity: The construction industry is physically demanding daily tasks often require; prolonged standing, bending, and lifting. A wide variety of tools may be used to provide more convenient work conditions (Inyang et al., 2013). By designing a task that incorporates less movement and a suitable reach the workspace becomes neater and workers become more productive.

Improved safety: Ergonomics helps in creating a safer environment by fitting tasks to the physical characteristics of the laborer. Studies have shown that a safer environment motivates the workforce (Koningsveld & Van der Molen, 1997). By providing the appropriate tools for specific tasks, chances of injuries are widely reduced.

Enhanced quality: According to previous studies, workers become more dedicated to their work when working in a better work environment, positively impacting employees' performances and leading to increased work quality (Jazani & Mousavi, 2014).

CASE STUDIES OF CONSTRUCTION SITES IN LEBANON

The following section presents results from case-study analysis on two different construction projects in Lebanon. These projects are medium-scale residential projects executed by local contractors and were selected to represent the majority of medium-scaled residential projects in Lebanon.

JOUNIEH CONSTRUCTION SITE

The case study is a medium scale project in Jounieh; a coastal city in Lebanon located 20 km north of Beirut. The project is an eight-storey residential building, the area of each floor is 350 m^2; the project is six month behind schedule and there is an increasing need to improve production. The aim of this study is to; identify current work inefficiencies caused by poor work planning as well as find cost effective and implementable modifications that can improve work efficiency. The site is adequately representative of typical Lebanese construction sites where; work conditions are poor, safety regulations are not enforced, and problems are magnified making them easy to spot.

The authors began by touring the workspace, observing workers as they perform different tasks. The foreman on site stated that the project was suffering from delays, identifying; poor productivity and labor absenteeism as major culprits. Subsequently, workers were asked about any work related ailments. At first workers were reluctant to cooperate out of fear of being reprimanded, this attitude shifted after explaining that the study is research oriented. The study identified a set of problems that hindered work processes; what follows is a summary of the survey that was made on site with both skilled workers and helpers regarding; back pain (BP), neck pain (NP), shoulder pain (SP), headache (H), and fatigue (F). The study was conducted on 25 workers. Percentages were rounded to the nearest five percent.

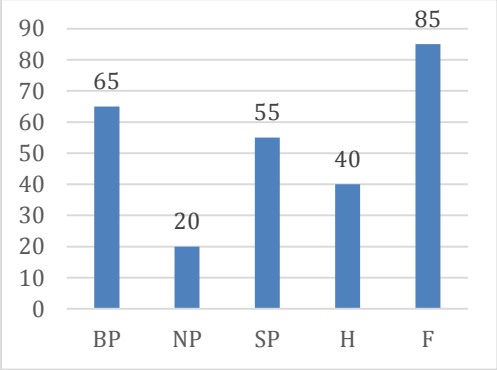

Figure 1: Percentage of Different Pains among Skilled Workers

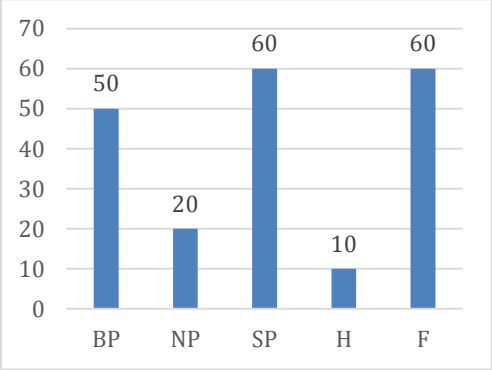

Figure 2: Percentage of Different Pain among Helpers

During the site visit the authors recognized that many problems related to work processes could have been prevented with some creativity. Both labourers and managers were interviewed to get a complete representation.

Table 1: Selected results of Interviews with Workers

Questions to workers	Responses received
Is pain part of the job?	Yes, construction is for those that are able to handle pain and push through it.
Have you thought about different ways your job could be done?	Yes, for some tasks we wish it could be done differently, but it is hard to negotiate with the management or to get certain tools.
Are you involved in any decision making?	No, we are told what to do and we make sure to do it.
Do you think that your input would be helpful?	Yes, many times we tried to warn the superintendent and he ignored our input

Table 2: Selected results of Interviews with the Managers

Questions to managers	Responses received
Do you think the labor force is skilled?	Some of the workers have years of experience under their belts, they are great, but not all of them.
Do you think some tasks could be done differently?	Construction work is a very old occupation and has been tweaked to become optimized, things you learn in school are theory and do not apply to real life.
Do you ask workers for their input?	No, we just push the instructions that come from our superiors
Are you concerned with the injuries that happen?	Yes, we regard the workers as our own kids, but injuries are an unfortunate part of construction.

As seen in the interview responses, the problem resides in people's mentality. Workers think that pain and injury are part of the job; ergonomics suggests otherwise, Taichi Ohno strived to improve tasks so that his workers do not have to sweat. The current state is a complete disregard for employee feedback, whereas the lean approach revolves around the respect of workers. The way things are currently done on Lebanese construction sites is far from lean. The authors think that the problem lies in the way people perceive work. A shift from a traditional to a lean mentality would greatly benefit the state of the construction sector in Lebanon and would tear down those barriers that prevent efficient work and block the way for new methods that would; generate value, increase productivity, and promote continuous improvement.

KHALDE CONSTRUCTION SITE

The Khalde construction site is a medium scale project for residential buildings. Interviews were conducted with the workforce. Thirty-two workers were asked several questions and answers where based on a five point scaling system (2: strongly agree, 1: agree, 0: neutral, -1: disagree, and -2: strongly disagree).

Table 3: Survey Results for Khalde Construction Site

Statement	Rating				
	-2	**-1**	**0**	**1**	**2**
Work conditions need improvement	8	15	6	3	0
Your job is physically demanding	0	15	3	11	3
You receive proper training for your job	0	7	3	17	5
You frequently bear work related injuries	3	6	2	14	7
You suffer chronic pain because of your work?	0	11	2	13	6

The Questions were chosen in order to highlight the problems that are occurring on construction sites. For example; most workers disagreed with the statement "Work conditions need improvement"; at the same time the majority reported frequent work related injuries. In addition, workers believe that they received proper trainings for the job yet, many of them suffer from chronic pains; a typical indicator of poor work form. In a nutshell; workers are not aware of the presence of a problem despite clear indicators.

Further Elaboration on Site Visits

What follows are some problems that were encountered in the workspace.

Table 4: Problematic Practices on Lebanese Construction Sites

Problematic Practice	Comments
Bending body parts	Most redundant, especially working under knee level and bending the back in an uncomfortable position.
Lifting heavy weights	Cement bags, masonry blocks were lifted manually with no equipment aid.
Working in awkward position	Bad sequencing of tasks often forced workers to work in an uncomfortable position. Example: interior block wall completed before exterior one.

Working in restricted space	Bad site layout and work space disorder causing serious space limitations.
Heat stress and dehydration	Dizziness, blurred vision and tiredness indicating a lack of hydration strategy.
Ignoring injuries	Workers admitted that they often worked despite physical pain and discomfort to avoid repetitive absenteeism.

In order to better document and highlight these issues photos were taken and collected for further analysis and discussion. Some of the photos are reported below.

Figure 3: Involvement of a worker lifting a heavy object

Figure 4: Worker exposing his back to potential injuries

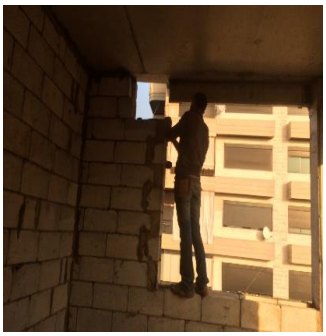

Figure 5: Dangerous work at height with no precautions

Figure 6: Restricted space creating lower productivity

Figure 7: Working in awkward and restricted space

Figure 8: Working at a dangerous height with no Scaffolding

The following section elaborates on some simple and cost effective methods that can be used to improve the work environment.

Construction work requires lifting heavy material; this naturally increases the risk of work related injuries. Work on the visited construction sites relied heavily on the

availability of a crane; workers stated that this equipment came as a major relief; improving their performance and the speed at which they completed tasks. For example, the transport of steel reinforcement bars from the ground floor to elevated floors was facilitated by the crane. However, workers complained that there was a need for a similar tool to move heavy materials horizontally on the same floor. A simple hydraulic scissor lift can be used; the tires at the base of the platform allow a weight of up to half a ton to be safely moved across the floor space, and the hydraulic lifting mechanism provides an effortless lifting mechanism.

Furthermore, in order to resolve the issue of working in awkward positions, the scheduling of tasks should be done with the construction process in mind. A better outcome is expected in the case where the workforce is consulted before finalizing the weekly schedules.

To solve the problem of working above shoulder height, a pecolift (lifting platform) or a similar tool could be used to facilitate the work.

Another problem arising on site is heat stress due to elevated temperatures during summer days and the absence of site ventilation. This problem should be seriously addressed since it has major consequences on safety and efficiency. The site should be equipped to handle such hot days; reflective shields could be used to reduce radiant heat and fans to ensure constant air flow, additionally water should be readily accessible.

Table 5: Comparison between Traditional Construction and Ergonomics Planning

Traditional construction project		**Ergonomics in construction**
Weights are manually handled	**Weights**	Handy cheap tools
Workers work in awkward position	**Positions**	Tasks are physically fit (pecolift)
Workers are unaware of heat stress and minimal preventive actions are taken	**Heat**	Safety induction, shades, fans, and other ventilation systems are provided
Workers ignore prevalent injuries	**Prevalent injuries**	Workers address prevalent injuries and take rest if needed

SYNERGY BETWEEN LEAN AND ERGONOMICS

While reviewing the benefits of ergonomics a strong similarity with the principles of lean thinking is apparent. Introducing ergonomic planning on construction sites will lead to fewer job related injuries. Furthermore, eliminating waste is at the heart of the Toyota production system (Liker, 2004). When a worker is injured, he will either stop working or work at a lower rate. This could be categorized as waste due to lost time, reduced productivity, and wasted opportunities.

In addition, variability in production is a central concept in the Toyota Production System (TPS). According to the lean philosophy, variability is a major cause of delays and production inefficiencies. By limiting injuries and standardizing work processes, ergonomics is also insuring a proper control over variability.

Finally, Ergonomics fits into one of the most important pillars of lean construction which is its philosophy. Lean advocates' stress on the fact that lean is not simply a set of tools to be applied, but rather a whole philosophy that should be cherished and lived by. Lean encourages the pursuit of long term targets even at the expense of short term financial goals. Implementing Ergonomics would come at costs but proves to be effective in the long run. The synergy between lean and ergonomics is summarized in the below figure.

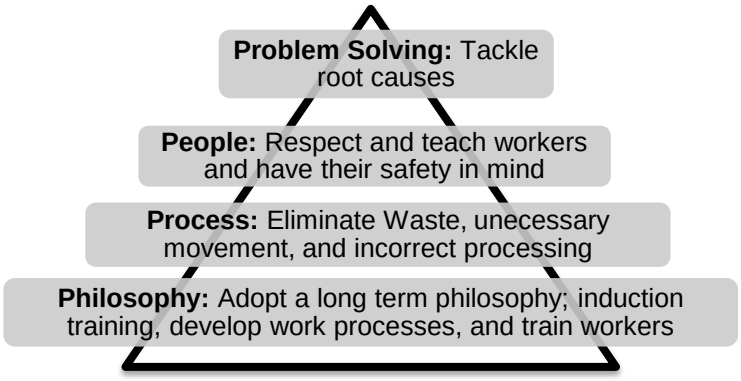

Figure 9: Ergonomics Fitting in the Lean Triangle

BARRIERS FOR IMPLEMENTING ERGONOMICS IN LEBANON

Despite the emergence of ergonomics as an advantageous work preparation approach, there exist numerous obstacles that are relevant to the case of Lebanon

Inertia: Justifications for disregarding ergonomics range from old sayings such as "this is the way we have always done it", charging problems on workers, to claims that ergonomics is not an "exact science" (Hwaiyu Geng, 2004). In Lebanon, the cultural behavior plays an important role, contractors; are satisfied with the current work methods, resist change, and view propositions as insults.

Financial: Adding a cost to the overall bill is not attractive for contractors, since contractors tend to look for cheaper construction methods that would give them a competitive edge in the bidding process (Glimskar & Lundberg, 2013). Contractors lag a long term vision, they save money where they should not but spend extra money on liquidated damages and costs related to work injuries.

Time: Ergonomics involves the addition of simple and innovative tools that enhance work productivity; however, some of these tools will require additional training for workers to familiarize themselves with the new methods. This idea of change is not attractive for workers and contractors who tend to resist change (Wiberg, 2012).

CONCLUSION

After studying two Lebanese construction sites, it was shown that ergonomics can bring successful results, help improve productivity, and reduce construction time and cost. However, for many reasons, contractors resist change. Traditional contractors believe that making workers work harder and longer will result in a lower construction time and cost. Taiichi Ohno quoted: "Why not make the work easier and more interesting so that people do not have to sweat?" Teamwork, accepting new ideas, working smarter not harder, and trust between the contractor and the workers need to be increasingly present throughout the construction phase in order to implement ergonomics.

To conclude, for a contractor to benefit from ergonomic planning, he or she should be willing to undergo radical changes at the methodical level. Contractors in Lebanon lack respect for workers where decisions are taken without the involvement of downstream player largely increasing the chances of rework and decreasing productivity

REFERENCES

Abrey, M., & Smallwood, J. J. (2014). The effects of unsatisfactory working conditions on productivity in the construction industry. Procedia Engineering, 85, 3–9. http://doi.org/10.1016/j.proeng.2014.10.522

Geng, H. (2004). ERGONOMICS. Manufacturing Engineering Handbook. McGraw Hill Professional, Access Engineering. Retrieved from http://accessengineeringlibrary.com/browse/manufacturing-engineering-handbook/p2000ad2999758_1001

Glimskar, B., & Lundberg, S. (2013). Barriers to Adoption of Ergonomic Innovations in the Construction Industry. Ergonomics in Design: The Quarterly of Human Factors Applications, 21(4), 26–30. http://doi.org/10.1177/1064804613488890

Inyang, N., Al-Hussein, M., El-Rich, M., & Al-Jibouri, S. (2013). Modification of Advanced Programmatic Risk Analysis and Management Model for the Whole Project Life Cycle ' s Risks. Journal of Construction Engineering and Management, 138(January), 51–60. http://doi.org/10.1061/(ASCE)CO

Jazani, R. K., & Mousavi, S. (2014). The Impacts of Ergonomic Aspects on the Quality, (March), 15–21.

Koningsveld, E. a P., & Van der Molen, H. F. (1997). History and future of ergonomics in building and construction. Ergonomics, 40(10), 1025–34. http://doi.org/10.1080/001401397187586

Smallwood, J. (2012). Mass of materials: the impact of designers on construction ergonomics. Work (Reading, Mass.), 41 Suppl 1(SUPPL.1), 5425–30. http://doi.org/10.3233/WOR-2012-0842-5425

Smallwood, J., & Ajayi, O. (2006). The impact of training on construction ergonomics knowledge and awareness, 2007(1), 1–17.

Tarhini, A., Fakih, M., Arzoky, M., & Tarhini, T. (2015). Designing Guidelines to Discover Causes of Delays in Construction Projects: The case of Lebanon. International Business Research, 8(6), 73–88. http://doi.org/10.5539/ibr.v8n673

Thomas, H. R., Horman, M. J., de Souza, U. E. L., & Zavřski, I. (2002). Reducing Variability to Improve Performance as a Lean Construction Principle. Journal of Construction Engineering and Management, 128(2), 144–154. http://doi.org/10.1061/(ASCE)0733-9364(2002)128:2(144)

Wiberg, V. (2012). Communication of Ergonomics in building and construction, 41, 4111–4115. http://doi.org/10.3233/WOR-2012-1038-4111