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# Stress Fracture: Adverse Effects of Lean Initiatives

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# Stress Fracture: Adverse Effects of Lean Initiatives


## Abstract

In today's highly competitive workplace, stress has become an important topic of interest due to its negative impacts on employee performance and health. As leaders attempt to create high performance and agile work environments, the importance of individual performance increases, which, in turn, relies on individual employees' well-being (health). This paper investigates to what degree, if any, prospective Engineering Managers understand the relationship between the implementation and execution of Lean initiatives and increased levels of employee stress.

The literature review associated with this project indicates that Lean activities can cause increased stress among employees, despite the many overall organizational benefits. Further, the literature indicates leadership is an important element in the complex stress-employee construct. However, the quantitative data collection in this study reveals that students in the fields of engineering and management do not consider increased stress to be a potential outcome of implementing Lean projects. In addition, the analysis of the survey data identifies opportunities to assist Engineering Managers in effectively dealing with the negative effects caused by Lean activities.

Finally, the results are used to present recommendations for educational and managerial training, so leaders can develop better ability to address the important issue of employee stress in today's high performing, quality-driven, organization.



## Keywords

Lean Initiatives, Organizational Behavior, Stress, Leadership, Socio-Technical Systems


## Introduction

Higher complexity, as well as increasing instability of global markets, make it necessary for organizations to continuously improve their competitiveness. As a result of permanent landscape changes in our workplaces, companies throughout the world are shifting towards the use of optimization strategies such as Lean Production (in the following "Lean"), to meet the challenges. According to literature, any current manufacturing {service} company that intends to be competitive must implement some aspects of Lean principles[1]. However, aside from cost reductions and increasing process efficiency, an implementation of Lean may involve risks, especially in terms of employees' psychological well-being[2].

The implementation of Lean systems has the potential to become a highly disruptive organizational change. It becomes apparent that prioritizing waste reduction or other technical (impersonal) issues over employee well-being can have detrimental consequences for the organizational performance, especially when leaders adopt a "home run" mentality during implementation. As a result, negligence of employee stress may negate the intended potential long-term gains. In scenarios where managers do not recognize the potential negative impacts of Lean on employee behavior, this lack of knowledge can be regarded as wasted potential on the journey to achieve maximum organizational performance.

The findings of this project should prevent impaired health and perhaps improve one of the cornerstones of Lean: employee involvement and motivation. This will play a vital role in securing future employees' well-being and could help facilitate sustainability of Lean. In summary, the purpose of this project is to describe the theoretical background of the potential negative impacts of Lean on employee well-being, collect data that proves missing awareness and knowledge among prospective professionals, and present novel efforts regarding implementation of these findings on an educational, managerial, and organizational level. More specifically, the educational implications will be useful for both preparatory (traditional engineering education) and on-the-job training (OJT).

Data for this study will be mined from students studying engineering at the undergraduate and graduate level, both nationally and internationally. It is the authors' belief the population is representative of current and future leaders who will be task with implementing Lean initiatives. Further, members of this population will represent the full spectrum of experiences with Lean—no knowledge thereof to implemented some component of a Lean project.

## Literature Review

### Organizations as a Socio-Technical System

To describe how changes in the work design and implementation of Lean initiatives can have an impact on employees and their performance, it is necessary to examine an organization from a Socio-Technical Systems (STS) perspective.

In the field of industrial science and engineering, there are a variety of different systems that are analyzed and designed, and the criteria of distinction between those systems is always the primary and basic element. An organization can be considered a complex socio-technical system, consisting of a technical and a social subsystem. Organizations are defined as a social unit of people that are structured and managed to meet a need or to pursue collective goals. All organizations have a management structure that determines relationships between the different activities and the members, and subdivides and assigns roles, responsibilities, and authority to carry out different tasks. Organizations are open systems, thus they affect and are affected by their environment[3]. Consequently, the STS approach puts emphasis on the interaction between people and technology in complex organizational work designs.

The STS concept arose in conjunction with one of several field projects that were conducted by the Tavistock Institute in the 1950 British coal mining industry. He argued that social and technical systems were the substantive factors, the people, and the equipment. The economic performance and job satisfaction outcomes were dependent upon how well the substantive factors fit together. Despite their independency, correlative values also exist in that one requires the other for the transformation of an input into an output, which comprises the functional task of a work system. The latter part of his findings, fitting substantive factors together, describes the concept of *joint optimization* in socio-technical systems theory. It states that the relationship between the technical and the social subsystem represents a coupling of dissimilars which can only be jointly optimized[4]. As a result, in an STS, shared emphasis on achievement of both excellence in technical performance and quality in people's work lives is necessary to be successful. For the sake of completeness, it should be mentioned that a third component, environment, was added to the STS approach. These three components together include the people who work within an organization (social subsystem), the required technology to operate (technical subsystem), and the customers, government bodies, and suppliers which interact with the organization (environment)[3]. In the context of this study, the environmental component can be disregarded. In conclusion, to design effective STS, it is necessary to define effectiveness in both economic and human terms.

### Lean

The term Lean was first used by John Krafcik in 1988 in his article "Triumph of the Lean

Production System" and is closely related to the Toyota principles. Krafcik's research at MIT was continued in a study by James P. Womack and Daniel T. Jones and finally concluded in the famous book *The Machine That Changed the World*[5]. Today the book provides enduring and essential guidance to managers and leaders in every industry seeking to transform traditional enterprises into exemplars of lean success. In the authors' view, Lean should serve as a strategy to adopt the Japanese principles of the Toyota Production System (TPS) to make the American automobile industry as competitive as the Japanese manufacturers. In words of Womack and Jones, the adoption of TPS techniques will not only foster superior production, but it will also provide challenging and fulfilling work for employees at every level[5]. The Lean revolution has become an integral facet of most successful manufacturing industries. In fact, some might say the impact of the waste-elimination and variation-control paradigm has considerably influenced manufacturing and non-manufacturing operations alike.

Lean can be defined as a systematic approach to identifying and eliminating waste through continuous improvement by flowing the product (or service) at the demand of the customer[6]. Nowadays, there are a variety of different definitions of Lean utilized in literature. Shah and Ward's review on Lean definitions concluded with a simple explanation that summarizes some of the most important characteristics of Lean work systems. They define it as an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability[7]. It becomes apparent that an organization that operates Lean can be seen as a complex STS. The success of a Lean system depends on the joint optimization of both its integrated technical and social subsystem. To demonstrate the complex idea of this work design, it is useful to analyze the "House of Lean." It is important to mention that literature displays several approaches to visualize the Lean idea in the form of a house. In some cases, it is designed as a production system, which is based on the pillars *Jidoka (Quality at the Source)* and *Just-In-Time* (JIT). In other cases, the illustration embodies an overarching organizational philosophy in which *Respect for People* and *Continuous Improvement* are the pillars. The House of Lean can be regarded as a combination of both production system and philosophy and should be noted that all components are interdependent.

## Organizational Behavior

The general philosophy of Organizational Behavior (OB) is important as leaders try to understand the mechanisms in an organization that can increase or decrease employees' work attitudes (e.g. job satisfaction or organizational commitment) as well as job performance. In the context of this project, OB theory is important to understand as it relates to the harmful relations between the technical and the social subsystem in a Lean organization. Emphasizing the importance of motivated and empowered employees in an organization is necessary in today's workplace, but often, it is just not a genuine desire. For many managers, cost reductions, efficient technologies and processes, are organizational aspects deemed to be key performance indicators. Therefore, many leaders often overlook the importance of the people behind the machines, who add value to the products and implement efficient process technologies. In such cases, managers have not internalized the concept of Lean thinking. They discount the middle pillar of the House of Lean, which emphasizes motivation of the workforce.

OB is defined as a field of study devoted to understanding, explaining, and ultimately improving attitudes and behaviors of individuals and groups in organizations[8]. The theories and concepts found in OB are developed and identified in a variety of different fields, such as social psychology, organizational psychology, industrial engineering, and sociology. The complexity of this field of study is endless and research in OB can be applied to a great number of different industrial and economical cases. In consequence of the diversity of OB topics, it would be helpful for readers to understand the general relations between employees and job outcomes. However, that discussion extends beyond the scope of this project. In this project, stress is the primary concept being investigated.

Stress

From a biological perspective, stress is the reaction of the body to environmental changes. Various studies have defined stress differently, but in general terms it can be seen as a state of health that results from any condition that causes an individual to have a generalized psycho-physiological response which deviates from a state of equilibrium[9]. Stress-producing events or conditions are called stressors. The psycho-physiological response to those stressors might be either productive or destructive. If it negatively influences employees' well-being, it is called strain. Weiss describes strain in her studies as a psychophysiological response to stress, that deviates from a person's norm and may lead to illness[9]. In literature, the term *stress* is more generally used to describe situations in which stressors and strains are present. Given that this study only focuses on negative impacts on employees' well-being, the term stress will be used consistently as a synonym for strain. The aforementioned definition indicates that stress mainly impacts employees on an individual level. In practice, stress has an impact on the individual outcomes Job Performance and Organizational Commitment. Consequently, it also can influence the success of the organization itself. Research from a variety of sources shows that employee stress can be a serious financial drain for organizations. Some costs that are directly related to stress are safety and medical-related costs as well as costs for absenteeism and turnover[10]. Overall costs of stress in American industry are estimated to be $50 to $150 billion annually[11].

When stress is described in a facet model, there are some initial stresses in the workplace which affect human psychological and physical processes. Duration of stressors experienced, situational characteristics and personal characteristics can moderate the relationship between the initiating stress and the human processes and, therefore, also moderate the resulting stress to the person[12]. Personal characteristics are important to consider in this context because every individual might react differently to stress. The duration of stressors experienced can also have an impact on the human psychological and physical processes because of the body's responses to the occurring stress. The longer stress is experienced, the more exhausted a person becomes.

If the stress level remains high and the individual is not able to respond or adapt to the situation, the body begins to break down and exhaustion occurs. Possible consequences of the body's exhaustion are broad. For example, physiological impacts such as high blood pressure or headaches or psychological impacts like the inability to think clearly or depression might occur. Higher alcohol or drug use might be potential behavioral outcomes of stress[8]. In this project, the Karasek stress model was used to describe how stress might be generated in a Lean organization. Figure1 shows the stress implications as a result of workplace demands and employee autonomy.

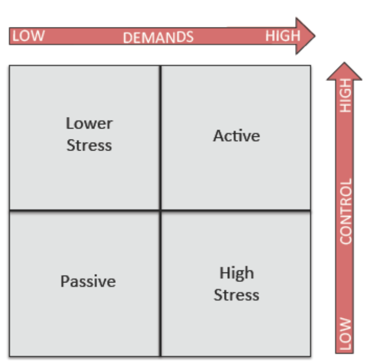


Figure 1: Karasek's Demand-Control Model of Job Stress[13].

In Karasek's model, workplace stress is a function of how demanding a person's job is and how much control, discretion, authority, or decision latitude the person has over his or her own responsibilities. This creates passive jobs, active jobs, jobs with a lower stress level, and jobs with a higher stress level. The first dimension, representing job demands, can be seen as the psychological stressors in the work environment. Examples for demands are time pressures, conflicting demands, pace of work, proportion of work performed under pressure, amount of work, or the degree of concentration required[13]. The second dimension in the model represents employees' control over their tasks and how those tasks will be executed. Decision authority describes both the employee's ability to make decisions about his or her own job and how to execute it as well as the employee's ability to influence his or her own work or work team and more general company decisions and policies. It becomes apparent that the outcome of the combination of high job demands with low job control is high stress.

## Management and Leadership

In recent years, many organizations considered management of stress as a personal matter of the employees. However, Lawless found that nine out of ten employees felt that it was the employers' responsibility to reduce worker stress. She emphasized employees have no doubt that stress-related illnesses and disability should be taken seriously. Employees expect substantive action by their employer and hold their employer financially responsible for the consequences of job stress[14]. As described by Peter Drucker, an expert in the fields of management and leadership, managers in an organization can have a great impact on the working environment of employees and thus have great responsibility for the work and well-being of their subordinates.

Considering a Lean organization from the STS perspective, management and leadership can be seen as the balancing element between the social and the technical subsystem. In general, it is difficult to give a precise definition of the term *management* because there are different disciplines that view and interpret management from different perspectives. One of the leading management thinkers, Lawrence Appley, defines management as guiding human and physical resources into dynamic, hard-hitting organization unit that attains its objectives to the satisfaction of those served with a high degree of morale and sense of attainment on the part of those rendering the service[15].

Leadership, as being an important part of management, is performed by people, through people, and for people. It is a social process concerned with interpersonal relations[15]. A leader needs to consider different mechanisms that allow him to change employees' perceptions and behaviors to improve their working environment and consequently their well-being. Most of these mechanisms focus on the development of organizational designs, structures, procedures, internal rituals, employee involvement and training, and organizational culture and philosophy[16]. Within these mechanisms, managers and leaders can choose from a variety of different tools and approaches that allow them to analyze and understand the interconnections between humans and their working environment. Considering a statement from Dr. Hans Selye, who is the leading stress expert in the industrial context, it becomes apparent why there is clear potential for reducing employee stress through interpersonal managerial action, rather than through redesigning the technical system. He explains, it is not stress that kills us, it is our reaction to it[17]. Managers are able to influence employees' reaction to stress in a Lean system by using different stress management approaches. This could be accomplished, for example, through feedback, communication, or employee involvement, both in the Lean implementation and in the operation of Lean systems. This would not only help managing stress caused by the practices and the implementation itself but also help managing the uncertainty caused by the change processes. As described in literature, the role of management seems to be the most important aspect when it comes to preventing negative effects on the working environment and employee health and well-being[17].

The basis for the creation of a supporting organizational culture is that stress is continuously identified, diagnosed, and addressed by management. The characteristics of a Lean culture are that all members of the organization have internalized the Lean philosophy and have implemented Lean thinking in their daily working habits. It takes a lot of time before a company can declare that it has a Lean culture because the culture of the company that existed before the change has to undergo fundamental change in values, priorities, norms of behavior and employee attitudes[18]. The role of management in changing the organizational design is often underestimated[19]. Employees must first believe that management is committed to the work design approach, so they are willing to change their attitudes and finally accept the work design. Therefore, the management system needs to be converted as well. Contrary to old work design approaches, like Taylor's and Ford's mass production, which were focused on results, Lean focuses more on processes, efficiency, and flexibility. In this more reliable and flexible solution, organizational success is more dependent upon the people running the processes. Consequently, people require all sorts of maintenance and attention themselves[19]. This can be directly related to the stress that is inherent in a Lean system. In the context of this project, maintenance and attention can be seen as stress management and can be illustrated by strong interpersonal interrelations that become necessary within the social subsystem of a STS. In such a Lean system, it is required that managers and leaders recognize the importance of those relations, to be able to set up and maintain them to successfully manage stress.

As a result, there is strong evidence identifying a need for managers and leaders to have knowledge about the potential occurrence of stress and be prepared for their work with employees in a Lean system. Basic knowledge and awareness of the negative consequences will likely increase the probability that employee stress becomes an issue, and managers are willing to take action. A basic understanding of the interrelations would also make it much easier for the people in power to particularly understand the stress inherent in the Lean system they are operating. This can help to develop and exercise individual stress management programs, which could assist managers in better coordinating human and physical resources to attain the organization's objectives of being successful.

## Methodology

It is important to mention the established effectiveness of a proper Lean implementation should not be questioned in this project. Rather, the goal of this research is to investigate concerns about the byproducts of Lean that are not communicated broadly in the literature. In consideration of the importance of management and leadership, this data collection should emphasize that engineering and management students, who represent the next generation of managers and leaders in industry, do not learn about stress as a possible outcome of Lean. Thus, the research hypothesis seeks to understand student awareness of potential negative impacts of an implementation of Lean and its methods. Finally, the findings of this data collection should fuel debates in both academic and business environments.

## Instrument Design

The quantitative data collection method in this project was a survey. It was chosen because of its well-known advantages as a primary data collection approach. The survey was advantageous because of its low cost, perceived anonymity, and ease of distribution. To gather responses from geographically dispersed regions, an online survey was deployed. The questionnaire that was distributed consisted of four different parts that are relevant for the research questions.

Part 1: The first section of the questionnaire focused on general demographic and topic related data. The questions in this part gathered information concerning gender, field of studies, degree being pursued, country of studies, and prior experience with Lean.

Part 2: Section two posed multiple-choice questions that asked about respondents' knowledge of some of the outcomes of an implementation of Lean and its practices. Each question provided eight different options from which to choose. Six options were related to positive outcomes, such as higher process efficiency or cost reductions, whereas one option always represented higher stress for employees. For consistency, all questions in this section contained the stress related options in the same diction. This helped to avoid respondents showing bias regarding the options that include the word *stress*. In addition, there was always one option per question that indirectly was related to higher stress. In addition to the pre-formulated options, each item also offered an open-ended option in which respondents could communicate their own thoughts.

Part 3: The third section of the instrument included questions about students' knowledge of the terms Muda, Muri, and Mura. From a variety of options, respondents were asked to select the terms they were familiar with prior to taking the survey. One of the questions was displayed in the form of a matrix and asked respondents about the meaning of the three terms. In answering this question, respondents were asked to assign each row to one of the columns in the matrix. The last question in this section asked whether students had learned about possible negative outcomes of Lean initiatives.

Part 4: In the instructions for completing the fourth section of the instrument, it stated there are several studies existing in literature that prove that employee stress might be directly related to an implementation of Lean and its practices. Subsequent to this statement, the respondents were asked in a multiple-choice question to indicate how they would address the relation between Lean and the employee well-being in an organization. This section also provided an open-ended option in which respondents could communicate their thoughts.

Two versions of the questionnaire were prepared to ensure that both English and German speaking students had the opportunity to answer the questions properly. Both versions were identical and were pre-tested and compared several times by multilingual test respondents. The questionnaires in English and German can be viewed in Appendix A.

## Instrument Vetting

Subsequent to formulating the research question and selecting the population, the next step in the data collection was to develop an appropriate questionnaire. After setting up a first draft, a great deal of pre-testing was necessary to develop the final content and structure of the survey questions. Pre-testing is the use of a questionnaire in a small pilot study to ascertain how well the questionnaire works[20]. The importance of pre-testing is pointed out by Backstrom and Hursch, no amount of intellectual exercise can substitute for testing an instrument designed to communicate with ordinary people[21].

In this project, pre-testing was necessary since there was a thin line between what respondents really knew about Lean and what they might take into consideration when reading the items, particularly when participants read the stress-related option provided in each question which may have biased their responses. As described in literature, the problem of misinterpreting questions is important to consider when developing a questionnaire. Consequently, after the test persons filled out the questionnaire in the pre-testing phase, it was necessary to get feedback from the respondent to ascertain how the respondent interpreted each question and whether the respondent had problems with any question[21].

In the pre-testing phase of the Lean questionnaire, it became apparent that nearly all 30 testers immediately started to think about stress as an outcome of an implementation of Lean and its practices. They all acknowledged in a subsequent interview that some of their responses were not based on their actual knowledge. As a result, the feedback in the pre-testing phase was necessary in order to reduce the error of interpretation. Basically, to avoid the bias, it would have been best to ask open-ended questions or to interview the respondents face-to-face. Since open-ended survey questions and face-to-face interviews are time consuming and impractical for the target population, the approach was set aside. Instead, based on the test persons' feedback, the questions were rephrased, improved, and tested until the final version could be delivered to the target population. The final questionnaire has been reviewed and is approved by the Rose-Hulman Institute of Technology (RHIT) Institutional Review Board (IRB).

## Population and Sample

In this survey, the observed population are students studying in the fields of engineering or management. This population was targeted because it is hypothesized that many of the respondents will become managers or will be leading individuals/teams in their careers in different organizations in industry[22]. Referring to the role of management in an STS, it becomes apparent that engineering and management students represent the population that will serve as the balancing element between the social and technical systems organizations. Consequently, many of the respondents will be directly engaged with Lean implementations or practices during their daily work.

A sample of convenience was chosen to execute this project. Given the connections to several academic institutions, both stateside and abroad, the authors targeted a select group of American and German universities. More specifically, Otto-von-Guericke University Magdeburg, Technical University Braunschweig, Technical University of Applied Science Wolfenbüttel/Wolfsburg/Salzgitter, Rose-Hulman Institute of Technology, Indiana State University, and the University of Washington. Unfortunately, within the specific context of higher education research, most contemporary survey response rates would be considered low from a historical perspective. Given this insight higher education researchers should not complacently accept low response rates as par for the course, but rather strategically strive to minimize survey non-response[23]. As such, a lottery-based incentive was employed to in an attempt to maximize response rates. Additionally, the survey we distributed to a few listservs maintained by the American Society of Engineering Education (ASEE).

## Hypotheses

In this project, the authors used a series of hypotheses to better understand the impact of Lean initiatives, including initial implementations, on employee stress. The following table displays the null hypotheses and the corresponding items on the survey instrument.

Table 1

| No. | Null Hypothesis | Survey Part | Item Number |
|---|---|---|---|
| $H_1$ | $P \geq 20\%$ of students in management and engineering consider employee stress as some of the outcomes of an implementation of Lean. | 2 | 8 |
| $H_{2.1}$ | $P \geq 20\%$ of students in management and engineering consider employee stress as an outcome of implementing the Lean practice of standardized work methods. | 2 | 9 |
| $H_{2.2}$ | $P \geq 20\%$ of students in management and engineering consider employee stress as an outcome of implementing the Lean practice of Just-in-Time (pull-production). | 2 | 10 |
| $H_{2.3}$ | $P \geq 20\%$ of students in management and engineering consider employee stress as an outcome of implementing the Lean practice of zero defects. | 2 | 11 |
| $H_{2.4}$ | $P \geq 20\%$ of students in management and engineering consider employee stress as an outcome of implementing the Lean practice of continuous improvement | 2 | 12 |
| $H_{2.5}$ | $P \geq 20\%$ of students in management and engineering consider employee stress as an outcome of implementing the Lean practice of visual management | 2 | 13 |

| | | | |
|---|---|---|---|
| $H_{2.6}$ | $P \geq 20\%$ of students in management and engineering consider employee stress as an outcome of implementing the Lean practice of employee empowerment, task variety, and cross-training. | 2 | 14 |
| $H_{2.7}$ | $P \geq 20\%$ of students in management and engineering consider employee stress as an outcome of implementing the Lean practice of waste reduction. | 2 | 15 |
| $H_{3.1}$ | $P \leq 20\%$ of students in management and engineering have heard about the term MUDA. | 3 | 16 |
| $H_{3.2}$ | $P \geq 20\%$ of students in management and engineering have heard about the term MURI. | 3 | 16 |
| $H_{3.3}$ | $P \leq 20\%$ of students in management and engineering know what MUDA represents. | 3 | 17 |
| $H_{3.4}$ | $P \geq 20\%$ of students in management and engineering know what MURI represents. | 3 | 17 |
| $H_4$ | $P \geq 20\%$ of students in management and engineering consider have learned about some negative outcomes of a Lean implementation. | 3 | 18 |
| $H_{5.1}$ | $P \leq 50\%$ of students in management and engineering think the relation between a Lean implementation and employee stress should be addressed through leadership strategies. | 4 | 20 |
| $H_{5.2}$ | $P \leq 50\%$ of students in management and engineering think the relation between a Lean implementation and employee stress should be addressed by providing training and education to prospective leaders/managers. | 4 | 20 |

## Results

The total number of valid responses to the survey was 326. A response rate was not possible to calculate, due to the inability of the authors to define the total number of students in the population. Geographically, the United States and Germany represented the largest percentage of respondents, 61.4% and 36.5% respectively. The balance of the respondents originated from students studying in Korea, France, and Switzerland. Time limitations and access to the survey lead to the uneven distribution of respondents.

Academically speaking, students selecting *other* (23.6%) as their major was the largest group of respondents. They were closely followed by students studying Industrial and Mechanical Engineering, 20.3% and 19.9% respectively. The disciplines of Electrical, Civil, Management (Economics), Chemical, and Systems Engineering followed thereafter. The largest percentage of the respondents were pursuing a Bachelor's degree (56.8%). Nearly 35% were studying at the Masters level and 7% at the Doctoral level. The balance of respondents were pursing the German credential of Diplom and Staatsexamen. Both represented 0.3% of the responding population. Additionally, 64.7% of the population was male while the 35.3% were female. Of the 326 respondents, over half (50.9%) indicated prior Lean experience. Students most often experienced Lean in an academic environment (76.9%). The balance of the respondents gained experience through an internship (37.5%), professional employment—full-time job, non-internship—(15.0%), or other means (13.1%). These categories were not mutually exclusive.

To make statistically verified statements, the data associated with null hypotheses were tested using Minitab's statistical software. In this project, the statistical software tools were used to test the null hypotheses and perform cross-tabulation and chi-square tests.

## Hypothesis Tests

For the hypothesis testing in this project, the one proportion test was used. A proportion is a relative portion of a whole, as opposed to a count or frequency. Proportions enable researchers to compare groups of unequal size. In particular, the one proportion test is used to estimate a population proportion and compare the proportion to a target or reference value. In this project, the test was used to determine whether the sample proportion differed from the hypothesized proportion that was specified in the particular null hypothesis. After the test, the software displayed a p-value that is based upon statistical factors calculated from the sample, the assumed distribution, and the type of test being done[24]. To finally test the hypothesis, the *p*-value was compared to a previously defined significance level. In this project, the significance level for rejecting the null hypothesis is $\alpha = 0.05$. That means that for $p \leq 0.05$ the decision is to reject the null hypothesis. In Table 2 the test results for each hypothesis are displayed.

Table 2. Hypothesis Decisions

| $H_x$ | Hypotheses Design | x | N | Sample *p* | 95% Bound | Exact *P*-value | Reject/Fail to Reject $H_0$ |
|---|---|---|---|---|---|---|---|
| $H_1$ | $H_0$: $p \geq 0.20$ vs. $H_A$: $p < 0.20$ | 12 | 326 | 0.036810 | 0.058958 | 0.000 | Rejected |
| $H_{2.1}$ | $H_0$: $p \geq 0.20$ vs. $H_A$: $p < 0.20$ | 21 | 326 | 0.064417 | 0.091440 | 0.000 | Rejected |
| $H_{2.2}$ | $H_0$: $p \geq 0.20$ vs. $H_A$: $p < 0.20$ | 50 | 326 | 0.153374 | 0.190077 | 0.019 | Rejected |
| $H_{2.3}$ | $H_0$: $p \geq 0.20$ vs. $H_A$: $p < 0.20$ | 31 | 326 | 0.095092 | 0.126178 | 0.000 | Rejected |
| $H_{2.4}$ | $H_0$: $p \geq 0.20$ vs. $H_A$: $p < 0.20$ | 23 | 326 | 0.098160 | 0.129599 | 0.000 | Rejected |
| $H_{2.5}$ | $H_0$: $p \geq 0.20$ vs. $H_A$: $p < 0.20$ | 15 | 326 | 0.046012 | 0.069968 | 0.000 | Rejected |
| $H_{2.6}$ | $H_0$: $p \geq 0.20$ vs. $H_A$: $p < 0.20$ | 52 | 326 | 0.159509 | 0.196692 | 0.037 | Rejected |
| $H_{2.7}$ | $H_0$: $p \geq 0.20$ vs. $H_A$: $p < 0.20$ | 46 | 326 | 0.141104 | 0.176792 | 0.004 | Rejected |
| $H_{3.1}$ | $H_0$: $p \leq 0.25$ vs. $H_A$: $p > 0.25$ | 101 | 326 | 0.309816 | 0.267573 | 0.009 | Rejected |
| $H_{3.2}$ | $H_0$: $p \geq 0.25$ vs. $H_A$: $p < 0.25$ | 62 | 326 | 0.190184 | 0.229526 | 0.006 | Rejected |
| $H_{3.3}$ | $H_0$: $p \leq 0.25$ vs. $H_A$: $p > 0.25$ | 85 | 326 | 0.260736 | 0.220949 | 0.347 | Failed to reject |
| $H_{3.4}$ | $H_0$: $p \geq 0.25$ vs. $H_A$: $p < 0.25$ | 25 | 326 | 0.076687 | 0.105462 | 0.000 | Rejected |
| $H_4$ | $H_0$: $p \geq 0.20$ vs. $H_A$: $p < 0.20$ | 93 | 326 | 0.285276 | 0.329302 | 1.000 | Failed to reject |
| $H_{5.1}$ | $H_0$: $p \leq 0.50$ vs. $H_A$: $p > 0.50$ | 203 | 326 | 0.622699 | 0.576303 | 0.000 | Rejected |
| $H_{5.2}$ | $H_0$: $p \leq 0.50$ vs. $H_A$: $p > 0.50$ | 186 | 326 | 0.570552 | 0.523580 | 0.006 | Rejected |

Fail to Reject Hypotheses

As illustrated in Table 2, only 2 of 16 null hypotheses were failed to reject. The first hypothesis that could not be rejected stated that $P \leq 25\%$ of students in engineering and management know meaning pf the Muda. With a percentage of $P = 26.0736\%$ and a lower 95% bound of $L = 22.0949\%$, the hypothesis could not be rejected. From the results, it can be concluded that more people than the hypothesized proportion answered they knew about the term. This becomes important when comparing the statistical results of the one proportion test of this hypothesis with the results of the hypothesis test about the term Muri. In comparison to Muda, only 26 respondents answered the question about the term Muri correctly and indicated that they know that Muri stands for “Waste of Overburden”. As a result, only 7.7% of the respondents knew the elimination of Muri is fundamental and a basic principle in the House of Lean. When comparing the 7.7% (Muri) with the 26% (Muda), some conclusions can be drawn. On an educational level, it can be derived that students in engineering and management are more informed about the reduction of the Seven Kinds of Waste than about reducing Waste of Overburden. It can be interpreted that students primarily learn about the former waste reduction principle more often. This could be because it can be directly related to measurable changes like cost cuttings, lower stock of inventories, or increased process efficiency. On the other hand, the reduction of Muri cannot be directly measured and recorded in common metrics.

The second hypothesis that was failed to reject stated that $P \geq 20\%$ of students in engineering and management have learned about some negative outcomes of an implementation of Lean. It was previously shown that 28.53% of the respondents answered they learned about negative outcomes in their prior experiences. This result is surprising when comparing the percentage to the number of respondents that identified stress in the previous questions to be an outcome of Lean. To identify those negative outcomes that students consider besides employee stress, further investigation is needed.

Rejected Hypotheses

As illustrated in Table 2, 14 of 16 hypotheses could be rejected. In summary, the statistical analysis of the collected data reveals that the members of the sample population are not aware of stress as a negative impact on a social subsystem in a Lean organization. The hypotheses tests clearly indicate that students in the fields of engineering and management do not think about stress as a potential negative outcome of an implementation of a Lean work design approach. Especially when considering the results of the one-proportion tests, it becomes apparent that most of the actual proportions are much smaller than the hypothesized proportions. Exemplary for the first hypothesis, which stated that $P \geq 20\%$ of the respondents consider higher employee stress to be a potential outcome of an implementation of Lean, only 12 persons of 326 selected the stress related option. With a percentage of 3.68%, the calculated proportion is more than five times smaller than the hypothesized proportion. It can be derived that only one prospective manager of 27 would take higher employee stress into consideration when he is confronted with a major work design change, as it is an outcome of the implementation of Lean. When bearing in mind that any manufacturing company today that intends to be competitive must have some type of Lean practices in place[26], the population’s lack of knowledge that has been revealed in this study becomes more meaningful. As identified in the last question, a great number of participants considered training and education for students and practicing managers to be effective strategies to bridge the existing gap of knowledge.

Cross Tabulation and Chi-Square Test

Cross tabulation and chi-square analysis are used when data is categorized by one or more categorical variables. With a cross tabulation and chi-square analysis, one can determine the counts or percentages for each category. This reveals if counts are distributed differently and helps to investigate some relationships between different variables. The joint frequency distribution can be analyzed with the chi-square statistic to determine whether the variables are associated or independent[24].

The first question of part two asked in general about respondents’ knowledge of some of the outcomes of an implementation of Lean. It was assumed that at this position in the questionnaire the respondents were still unbiased, because they could not read the subsequent questions and stress related options. Hence, this particular question was used for the cross tabulation analysis. It illustrated what knowledge students in engineering and management really encode when they hear the term Lean. Therefore, the following analysis of responses was used to identify some differences or similarities between the variables "Field of study," "Country of study," "Field of prior experience," and the frequency of people selecting the option "Higher stress for employees." The full table of results can be seen in the Appendix B.

The results of the cross tabulation test on the variables "Field of study" and "Country of study" showed only 12 respondents considered higher employee stress to be an outcome of an implementation of Lean. This quantity cannot be used to make statistically verified statements. To further investigate the impact of students' educational background or country of study on their Lean stress related knowledge, larger studies need to be completed. Again, it is underlined that the following explanations are based on assumptions and are not to be seen as statistically proven. In the data analysis, it was striking that 5 of 12 of the respondents that considered stress to be an outcome of an implementation of Lean are studying Industrial Engineering (41.67%). Another interesting aspect can be derived from the cross tabulation test, investigating the variable "Country of studies." Surprisingly, 10 of 12 of the respondents that considered stress to be an outcome of an implementation of Lean are studying in Germany (83.33%). In comparison, the other two respondents are studying in the US. Keep in mind that most respondents were students from Germany and the US, and as such, it becomes apparent why there is no representation from France, Switzerland, or South Korea that considered higher stress for employees.

## Implications

The learning objective of this project was not to judge Lean, but rather to use the findings to understand the interdependencies of Lean's technical subsystem and the workplace productivity. No other study exists literature that focuses on this specific population, but the findings clearly emphasize that prospective leaders and managers are not aware of employee stress as a possible outcome of Lean production. The findings in this study do not present ways on how to prevent or reduce stress. However, the findings can be useful in preparing managers to identify and address employee stress. In doing so, the end results can help increase Lean system performance. The following suggestions demonstrate how adaptations in education and organizational structure might have a positive impact on employee well-being and increased performance levels.

## Engineering Education

Many engineers become managers in their careers, and typically they are unprepared for the transition. Perhaps this can be explained by the assumption that engineers prefer working with physical entities and the laws of nature rather than managing idiosyncrasies of people. However, when taking into consideration that many engineers will manage employees or lead teams in their career, they must prepare for the challenges of being an effective leader.

The data collection in this study has indicated that students are knowledgeable about the beneficial outcomes of Lean, such as increases in efficiency or reduced costs. However, to understand the complexity of Lean organizations, students need to learn about the social subsystem and its influencing factors as well. Contemporary engineering education has to ensure graduates are prepared for their future roles in life and work. This role at work also includes managing and interacting with employees in complex organizational work designs. As described in literature about educating the engineers of 2020, future engineering education must be reengineered backwards starting at currently existing problems. It begins by identifying the desired outcome, product, or service, and then designing backward, using as design criteria what the outcome is supposed to look like and the nature of the processes used to produce it[27].

Considering the need for high-performing employees in Lean organizations in conjunction with the negative correlation between stress and higher performance levels, it becomes apparent that managers need stress management skills, especially, stress awareness. It is recommended to educate management and specifically engineering students in terms of developing technical and enhanced social expertise. This would include teaching both the advantages and disadvantages of a Lean work approach not only from a technical, but also from a social perspective. Current engineering education concentrates strongly on aspects regarding the technical subsystem. On the contrary, the consideration of interrelations between humans and the technical elements is more unidirectional. For example, the importance of humans and their role in the organization is often pointed out to emphasize their necessity for continuous improvement or high quality strategies. However, the reverse impact technical elements can have on humans is barely being discussed in the classroom. One possible reason could be a significant percentage of engineering faculty have no industry experience[28]. As pointed out by industry representatives, this disconnect might result in the fact that students are not adequately prepared to enter today's workforce[27]. Faculty industrial experience working with employees and managing individual Organizational Behavior outcomes, such as stress, is especially important to accurately explain complex socio-technical relations to students.

As effective leaders continue to emphasize the value of their human assets, it becomes more apparent that there is a need to address those issues in an academic environment, especially in engineering education. Two major changes can be suggested to address these requirements. First, engineering curricula and STS relations, for example employee stress, could be better aligned. Second, faculty skill sets could be developed to match those needed to prepare students for managing employees in a STS. For example, faculty can pursue internships or mini-sabbaticals to ensure they have the first-hand experience needed to prepare students for their future careers.

## Managerial

Stress reduction is often not considered to be one of the major tasks managers believe they will face in their work. This alone could account for the relative lack of organizational interventions for job stress[29]. In addition, managers are not well-prepared and simply do not know about stress inherent in Lean organizations. However, when considering that high costs arise every year that are directly correlated to employee stress, it becomes apparent that there is a clear need for intervention and stress management. In the following statements, it is assumed that there is no additional education regarding employee stress between graduation and the start of a professional career. Therefore, the findings in this study imply that the knowledge gap exists for future managers as well. More specifically, the next sections will address implications for educating engineers in two critical managerial areas: Stress and Change Management.

## Stress Management

In literature, many different approaches describe how to manage stress effectively.
However, in general, their structure and steps are identical. It can be derived that the first managerial task is to accept that employees are experiencing problems such as stress at work before thinking about strategies to counter stress. Taking into consideration that only 3.6% of the population in this research identified higher employee stress to be an outcome of an implementation of Lean, the first task should be a priority.

General awareness of the occurrence of stress in a Lean system can be seen as necessary groundwork for developing individual programs and strategies that particularly address employee stress in an organization[30]. If this groundwork is not developed in an academic environment, students' missing knowledge might affect the level of subordinates' performance once they graduate and start working as managers or leaders in industry.

Another important aspect to be mentioned is that engineers can only make good managers if they are willing to continue enhancing their skill-set beyond their initial academic studies. Management is a complex field influenced by a variety of factors, such as the organizational context and the specific setting. Consequently, practicing managers must still be willing to enhance their knowledge. This would help to further develop an understanding of both the organizational context and the various fast-changing administrative, financial, behavioral, and interpersonal issues that have to be considered in a Lean system. Enhancing the skill-set on a level that might influence employees' behavior and other interpersonal issues would be, for example, to continuously develop stress management and change management skills. Trainings and education of those managerial skills must be made available for managers through a standardized approach within the organizational structure. This would help to ensure that stress management becomes a continuous process, not a discrete program with temporal boundaries[30].

## Change Management

In general, change management and stress management go hand in hand. Change and the implied uncertainty for workers are especially important when considering the employee-stress relations in a Lean organization. To reduce the level of stress for employees, there must be better clarification and communication of the relationships between the technical and the social subsystems. These actions can assist in "getting the employees on board" and consequently help employees to better cope with stress. This clearly demonstrates a need for the fundamental understanding of STS relations and stress. Such basic understanding must be developed in higher education. If managers genuinely understand the mutual interrelations between the technical and the social subsystems, they can assess potential landmines in the Lean initiatives and communicate those issues to their subordinates.

The results from two studies in literature indicate some evidence for these implications. They state that the degree of employee involvement in the implementation process of a work design approach is particularly important for employee behavioral outcomes. The studies found that a weak change program with limited employee involvement accounted for the less positive outcome in two of the studied plants[30]. Other researchers, such as Conti et al., found a positive relationship between the involvement of employees in the Lean implementation process and the reduction of stress[31]. In summary, an increased educational and internal focus on potential outcomes of socio-technical relations in a Lean system are likely to decrease uncertainty and better manage change.

## Conclusion

Today's workplace will continue to be complex, challenging, and filled with competitive opportunities and threats. In times of increasing external uncertainty, internal organizational stability and work atmosphere have to be maintained and strengthened more than ever before. In the next century, there will be a number of developments in organizational forms that are as significant as those in the past. It can be concluded that organizational designs will never be perfect and that there will always be room for improvement. However, if there is one certainty, it is that one important milestone towards the next era of work design approaches will be to manage the human assets in an organization more effectively.

The aim of this study was to identify potentially harmful relations between the social and technical subsystems in a Lean organization, and subsequently, to understand prospective managers' knowledge about the findings. In particular, the effects of an implementation of Lean on employees' working environment were examined from a socio-technical (STS) perspective. This illustrated that technical elements in a Lean system can cause stress among employees. Based upon the findings, engineering and management students' knowledge of the revealed interrelations were tested through a questionnaire that was developed. The questionnaire asked respondents' about their knowledge of potential outcomes of an implementation of Lean and its practices. The results of the data collection included input from 326 respondents, which clearly uncovered prospective managers' missing awareness of employee stress as a potential outcome of an implementation of Lean. Consequently, the results of the practical research in this study, as well as the implications, can be seen as a contribution to the development of ways firms can engage their employees. Adjustments in undergraduate engineering education—including faculty preparatory experiences—was identified to be important for potential managers to effectively minimize employee stress.

As described by Liker and many other Lean experts, the problem is that many companies have embraced Lean tools but do not understand what makes them work together smoothly as a system. Typically, management tries to adopt a few of the technical tools but struggles to really implement them in their organization. Consequently, leaders must understand the value workers add to highly complex work systems. Therefore, studies such as this one are necessary for supporting the social needs in an organization. However, higher stress is only one of many possible outcomes that need to be addressed during lean activities. Given the significant number of engineering and management students that do not know about the existence of Muri and increased employee stress suggests that there is great additional potential for better preparing students for their future roles as leaders and managers.

Despite experts trying to measure and forecast productivity, no one will ever know the true extent of performance potential inherent in our organizations. Productivity in today's industry is judged by historical standards and technical data, rather than by percentage, which theoretically could be possible if all organizational interrelations were perfect. Contrary to technical processes and machines, which are improved and redesigned over and over again, the endless potential for increasing and developing human performance and innovativeness is yet unexplored. Strong evidence for the need of directing future research towards the significance of humans in increasing organizational efficiency is given by the rule of one eighth. It says that:

> *One must bear in mind that one-half of organizations won't believe the connection between how they manage their people and the profits they earn. One-half of those who do see the connection will do what many organizations have done – try to make a single change to solve their problems, not realizing that the effective management of people requires a more comprehensive and systematic approach. Of the firms that make comprehensive changes, probably only about one-half will persist with their practices long enough to actually derive economic benefits. Since one-half times one-half times one-half equals one-eighth, at best 12 percent of organizations will actually do what is required to build profits by putting people first*[32].

The rule impressively illustrates that future research in the fields of organizational design and reengineering of internal STS relations has great potential. The learning point of this study is not to judge Lean or any of its methods, but rather, based on findings, to examine Lean and employees' working environment in a productive and innovative manner. In doing so, it is possible to further increase the performance and success of existing and upcoming Lean organizations. Although Lean solutions can increase efficiency of the workforce, they should additionally attempt to improve the working conditions for employees as well. Thus, studies such as this one are capable of empowering future engineers and managers to develop strategies that have a long-lasting and value-adding impact on the 88% of organizations that currently lack this acknowledgement—the core value of Lean implementation is rooted in the employees.

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Appendix A:

# Lean Production - Questionnaire

This survey is IRB approved and your participation is completely voluntary. There are no foreseeable risks associated with this project.

Please do not go back in the progress to change your responses. It is very important for me to learn about your current knowledge about Lean.

Your survey responses will be handled confidentially. If you have questions about the survey or the procedures at any time you may contact me by email at the address specified at the end of the survey.

Please start with the survey now by clicking on the Continue button below.

* Required


## Part 1: Background

1. **If you want to take part in the $20 Amazon Gift Card draw, put your email address below:**

________________________________

2. **Gender** *

What is your gender? *Mark only one oval.*

- ◯ Female
- ◯ Male

3. **Field of studies** *
What is your field of studies? *Mark only one oval.*

- Mechanical Engineering
- Industrial Engineering
- Management/Economics
- Systems Engineering
- Chemical Engineering
- Civil Engineering
- Electrical Engineering
- Other

4. **Degree** *
What degree are you actually pursuing? *Mark only one oval.*

- Undergraduate (Bachelor's degree)
- Graduate (Master's degree)
- PhD (Doctor's degree)'
- Other: ____________

5. **Country** *
Where are you studying? *Mark only one oval.*

- USA
- Germany
- Other: ____________

6. **Lean** *
Do you have any experience with Lean? *Mark only one oval.*

- YES.
- NO.

7. **Lean**
If YES, where did you learn about Lean? *Check all that apply.*

- Academic experience (e.g. lecture)
- Internship
- Professional experience (e.g. job)
- Other: ____________

# Part 2: Lean

Imagine that the following changes take place in an organization. Check all answers that apply. In case that you are not familiar with a method, check "I did not learn anything about that."

8. **From your prior experience (e.g. academic, internship), how would you answer the following question?**
What are some outcomes of an implementation of Lean Production that you have learned?
*Check all that apply.*

- [ ] Process improvements.
- [ ] Higher standardization.
- [ ] Higher employee stress.
- [ ] Higher efficiency and organizational performance.
- [ ] Higher uncertainty for employees.
- [ ] Increasing product quality.
- [ ] Lower costs for inventory.
- [ ] I did not learn anything about that.
- [ ] Other: ____________________

9. **From your prior experience (e.g. academic, internship), how would you answer the following question?**
What are some outcomes of an implementation of standardized work methods that you have learned?
*Check all that apply.*

- [ ] Higher efficiency and organizational performance.
- [ ] Clean and organized work places.
- [ ] Reduction of waste.
- [ ] Reduced worker job control.
- [ ] Higher safety.
- [ ] Higher standardization.
- [ ] Higher employee stress.
- [ ] I did not learn anything about that.
- [ ] Other: ____________________

10. **From your prior experience (e.g. academic, internship), how would you answer the following question?**
What are some outcomes of an implementation of Just-in-Time/Pull Production that you have learned?
*Check all that apply.*

- [ ] Increased process flexibility.
- [ ] Lower costs.
- [ ] Lower work intensity.
- [ ] Higher customer satisfaction.
- [ ] Higher employee stress.
- [ ] Higher product quality.
- [ ] Higher work intensity.
- [ ] I did not learn anything about that.
- [ ] Other: ______________

11. **From your prior experience (e.g. academic, internship), how would you answer the following question?**
What are some outcomes of an implementation of a "zero defects" quality strategy (e.g. mistake proofing - "Poka Yoke") that you have learned?
*Check all that apply.*

- [ ] Lower costs.
- [ ] Higher organizational performance.
- [ ] Lower defect rate.
- [ ] Higher product quality.
- [ ] Reduced worker job control.
- [ ] Increased customer satisfaction.
- [ ] Higher employee stress.
- [ ] I did not learn anything about that.
- [ ] Other: ______________

12. **From your prior experience (e.g. academic, internship), how would you answer the following question?** What are some outcomes of an implementation of visual management ("andon lights") or line stop cords as a "Quality at the Source" strategy that you have learned? *Check all that apply.*

- Reduced costs.
- Higher efficiency and organizational performance.
- Higher stress for employees.
- Immediate feedback.
- Improved product quality.
- Individual blaming for defects.
- Higher customer satisfaction.
- I did not learn anything about that.
- Other: ____________________

13. **From your prior experience (e.g. academic, internship), how would you answer the following question?**
What are some outcomes of an implementation of a "Continuous Improvement" strategy that you have learned?
*Check all that apply.*

- Higher product quality and customer satisfaction.
- Higher stress for employees.
- Higher innovativeness.
- Lower costs.
- Increased role challenge.
- Higher employee performance.
- Higher process efficiency.
- I did not learn anything about that.
- Other: ____________________

14. **From your prior experience (e.g. academic, internship), how would you answer the following question?**
What are some outcomes of empowerment, greater task variety, and cross-skilling for employees that you have learned?
*Check all that apply.*

- Increased employee motivation.
- Increased employee performance.
- Increased role ambiguity for employees.
- Higher product quality and customer satisfaction.
- Increased role challenge.
- Higher stress for employees.
- Increased innovativeness.
- I did not learn anything about that.
- Other: ____________________

15. **From your prior experience (e.g. academic, internship), how would you answer the following question?**

What are some outcomes of the elimination of waste (e.g. wasted material, transportation) that you have learned? *Check all that apply.*

- Higher job intensity.
- Cost savings.
- Higher employee motivation.
- Higher employee stress.
- Increased product quality.
- Higher process efficiency.
- Higher organizational performance.
- I did not learn anything about that.
- Other: ______________

# Part 3: Lean

16. **Please answer the following question.**

Which of the following terms have you heard about? *Check all that apply.*

- MULAN
- MUDA
- MURI
- MURO
- MURA
- I have not heard about any of these.
- Other: ______________

17. **In case that you are familiar with one of the previous terms:** *

Complete the following table by assigning each row to one column. If you are not familiar, choose "I do not know". *Mark only one oval per row.*

| | Waste (7Arten der Verschwendung) | Waste of Overburden | Waste of Unevenness | Not existing. | I do not know. |
|---|---|---|---|---|---|
| Mulan | ○ | ○ | ○ | ○ | ○ |
| Muda | ○ | ○ | ○ | ○ | ○ |
| Muri | ○ | ○ | ○ | ○ | ○ |
| Muro | ○ | ○ | ○ | ○ | ○ |
| Mura | ○ | ○ | ○ | ○ | ○ |

18. **In your prior experience with this topic, did you learn about some negative impacts of an implementation of Lean?** * *Mark only one oval.*

- Yes!
- No!

19. **If YES, where did you learn about negative impacts of an implementation of Lean?** *Check all that apply.*

- Academic experience (e.g. lecture).
- Internship.
- Professional experience (e.g. job).
- Other: ______________

# Part 4: Lean

Several studies have shown that the implementation of Lean, as well as the work with Lean Methods can negatively affect the work environment and cause stress among employees (e.g. Landsbergis et al., Conti et al., Anderson-Connolly et al.).

20. **As a prospective leader/manager, how would you complete the following statement?** The relation between Lean and employee well-being should be addressed by the following: *Check all that apply.*

- Not using Lean Production.
- Laying off current workforce and hiring employees that are able to cope the stress.
- Adapting leadership strategies.
- Not important to address.
- Employees should cope with stress on their own.
- Paying more money to employees.
- Education/Training for (prospective) managers/leaders
- I do not know.
- Other: ______________

Appendix B:

| Tabulated Statistics: Country, Higher employee stress. | | | | |
|---|---|---|---|---|
| | Columns: Higher employee stress. | | | |
| Rows: Country | | FALSE | TRUE | ALL |
| France | Count | 1 | 0 | 1 |
| | % of Row | 100.0 | 0.000 | 100.0 |
| | % of Column | 0.318 | 0.00 | 0.307 |
| | % of Total | 0.307 | 0.000 | 0.307 |
| Germany | Count | 109 | 10 | 119 |
| | % of Row | 91.6 | 8.4 | 100.0 |
| | % of Column | 34,713 | 83,333 | 36,503 |
| | % of Total | 33,436 | 3,076 | 36,503 |
| Germany/USA | Count | 2 | 0 | 2 |
| | % of Row | 100.0 | 0.00 | 100.00 |
| | % of Column | 0.637 | 0.000 | 0.613 |
| | % of Total | 0.613 | 0.000 | 0.613 |
| Korea | Count | 2 | 0 | 2 |
| | % of Row | 100.0 | 0.0 | 100.0 |
| | % of Column | 0.637 | 0.000 | 0.613 |
| | % of Total | 0.613 | 0.000 | 0.613 |
| Switzerland | Count | 1 | 0 | 1 |
| | % of Row | 100.0 | 0.000 | 100.0 |
| | % of Column | 0.318 | 0.00 | 0.307 |
| | % of Total | 0.307 | 0.000 | 0.307 |
| South Korea | Count | 1 | 0 | 1 |
| | % of Row | 100.00 | 0.00 | 100.00 |
| | % of Column | 0.318 | 0.000 | 0.307 |
| | % of Total | 0.307 | 0.000 | 0.307 |
| USA | Count | 198 | 2 | 200 |
| | % of Row | 99.0 | 1.0 | 100.00 |
| | % of Column | 63,057 | 16,667 | 61,350 |
| | % of Total | 60,736 | 0.613 | 61,350 |
| All | Count | 314 | 12 | 326 |
| | % of Row | 96.3 | 3.7 | 100.0 |
| | % of Column | 100,000 | 100,000 | 100,000 |
| | % of Total | 98,319 | 3,681 | 100,000 |

| Tabulated Statistics: Field of studies, Higher employee stress. | | | | |
|---|---|---|---|---|
| | Columns: Higher employee stress. | | | |
| Rows: Field of studies | | FALSE | TRUE | ALL |
| Chemical Engineering | Count | 21 | 0 | 21 |
| | % of Row | 100.00 | 0.00 | 100.00 |
| | % of Column | 6.69 | 0.00 | 6.44 |
| | % of Total | 6,442 | 0.000 | 6,442 |
| Civil Engineering | Count | 24 | 1 | 25 |
| | % of Row | 96.00 | 4.00 | 100.00 |
| | % of Column | 7.64 | 8.33 | 7.67 |
| | % of Total | 7,362 | 0.307 | 7,669 |
| Electrical Engineering | Count | 42 | 0 | 42 |
| | % of Row | 100.00 | 0.00 | 100.00 |
| | % of Column | 13.38 | 0.00 | 12.88 |
| | % of Total | 12,883 | 0.000 | 12,883 |
| Industrial Engineering | Count | 61 | 5 | 66 |
| | % of Row | 92.42 | 7.58 | 100.00 |
| | % of Column | 19.43 | 41.67 | 20.25 |
| | % of Total | 18,712 | 1,534 | 20,245 |
| Management/Economics | Count | 20 | 2 | 22 |
| | % of Row | 90.91 | 9.09 | 100.00 |
| | % of Column | 6.37 | 16.67 | 6.75 |
| | % of Total | 6,135 | 0.613 | 6,748 |
| Mechanical Engineering | Count | 65 | 0 | 65 |
| | % of Row | 100.00 | 0.00 | 100.00 |
| | % of Column | 20.70 | 0.00 | 19.94 |
| | % of Total | 19,939 | 0.000 | 19,939 |
| Other | Count | 73 | 4 | 77 |
| | % of Row | 94.81 | 5.19 | 100.00 |
| | % of Column | 23.25 | 33.33 | 23.62 |
| | % of Total | 22,393 | 1,227 | 23,620 |
| Systems Engineering | Count | 8 | 0 | 8 |
| | % of Row | 100.00 | 0.00 | 100.00 |
| | % of Column | 2.55 | 0.00 | 2.45 |
| | % of Total | 2,454 | 0.000 | 2,454 |
| All | Count | 314 | 12 | 326 |
| | % of Row | 96.32 | 3.68 | 100.00 |
| | % of Column | 100.00 | 100.00 | 100.00 |
| | % of Total | 96,319 | 3,681 | 100,000 |