An International Lean Certification Role Delineation Delphi Study Applied to Develop Graduate-level Curriculum in Lean Manufacturing

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Abstract

The focus of this research was to conduct a role delineation study to validate and prioritize the competency areas to be included in the Body of Knowledge (BOK) for the SME/AME/Shingo lean manufacturing certification program. The lean certification program offers three certifications, at Bronze, Silver, and Gold levels. These three levels are aimed at recognizing tactical, integrative, and strategic applications of standard lean principles. A modified Delphi technique was used to gather data and describe what experts in the field consider important for candidates to know in order to become certified in the discipline of lean manufacturing. Seventy-six experts from six different countries selected to serve on the Delphi panel rated the importance of competency areas for testing at each level of lean certification using a five-point Likert scale and provided additional comments. A convergence of opinion on the competency areas provided a basis for validating the body of knowledge for Bronze, Silver, and Gold levels of lean certification examinations. A prioritized list of 42 competency areas that emerged from the study was organized as a BOK and grouped into five major domains: (a) Enablers for Lean, (b) Lean Core Operations, (c) Business Core Operations – Support Functions, (d) Quality, Cost, and Delivery Measures, and (e) Business Results. This paper will describe how the results that define the body of knowledge for the Silver level of the lean certification exam can be applied to develop the foundation for a graduate-level curriculum in lean manufacturing.

Introduction

According to Womack [1], lean business and manufacturing practices, along with high quality, are expected to save U.S. industry in the face of intense competition among manufacturing companies. In order to address the issue of identifying and employing skilled employees, certification in manufacturing by a third party can help to show that an individual has kept up with new developments in the field. Certification also provides individuals with a documented credential of proficiency in their profession. Moreover,

companies recognize the value of certification because certification gives an individual a sense of personal achievement, greater confidence, and a competitive edge over other individuals who are not certified [2].

Hogan [3] emphasized the need for lean certification based on a survey of more than 1,100 manufacturing industry respondents. Eighty-three percent of the participants in the survey mentioned that it was either critical or very important to develop an industry standard for lean certification. Moreover, a well-constructed job analysis study is an essential foundation for a valid, reliable, and legally defensible professional certification program [2].

The purpose of this study was to identify and validate the body of knowledge developed by SME/AME/Shingo for their three levels of certification examinations in lean manufacturing. The focus of the article will be to discuss the methodology used for the study and delineate the results obtained from the Silver level certification exam that can be applied to lay a foundation for developing a graduate-level curriculum in lean manufacturing.

Background Information on SME/AME/Shingo Lean Certification Program

The focus of the three levels of lean certification developed by a consortium of the Society of Manufacturing Engineers, Association for Manufacturing Excellence, and Shingo Prize is described below:

1. Bronze Certification – to measure the knowledge of basic principles, concepts, and tools of lean as applied to factory, office, service, team facilitation, and appropriate measurement of results

2. Silver Certification – to measure the capability of lean practitioners in applying lean principles and tools to drive improvements and show measurable results, as well as to orchestrate the transformation of a complete value stream

3. Gold Certification – the highest level, focused on evaluating the practitioner's strategically focused knowledge and solid understanding of all aspects of lean transformation across the entire enterprise

Each level of certification requires the applicant to pass a written examination consisting of approximately 150 questions within a three-hour time limit. According to SME [4], "Unlike other programs in the market today, lean certification is awarded based on experience, education, and mentoring—and it must be renewed." The experiential requirement for this certification is demonstrated through portfolio evaluation for the Silver and Gold levels.

Literature Review

Role Delineation Studies. A role delineation/job analysis study is the most highly recommended and extensively used technique to validate the body of knowledge for a certification examination. Hall and Tillman [5] recommended a role delineation study be conducted using a Delphi survey methodology, validated survey, or content specialist panel to determine competencies and job tasks. The Project Management Institute [6] conducted an international role delineation survey for the Project Management Professional (PMP) certification examination. Six major domains and sub-tasks were initially identified by technical experts, and then survey respondents were asked to rate these on the basis of importance, criticality, and frequency on a five-point Likert-type scale. Importance was defined as the degree to which it is essential for Project Management Professionals (PMPs) to be competent in the domain or task. Criticality was defined as the degree to which incompetence in the domain or task could bring about harm, while frequency was the percent of projects on which PMPs would perform duties associated with each domain. The sample size for this study was 826 professionals in the field of project management.

A similar role delineation study was also conducted by the Project Management Institute [7] for the Certified Associate in Project Management (CAPM) examination. The sample size for this study was 509 participants. A five-point Likert-type rating scale for criticality, importance, and frequency was used in the survey. The final phase of the role delineation study identified the proportion of questions from each domain and task that should appear on the certification exam. The overall evaluations of importance, criticality, and frequency were combined and converted into percentages for developing test specifications.

A job analysis study conducted by the Microsoft Company for its Microsoft Certified Systems Engineer (MCSE) certification [8] had a sample size of 415. A five-point Likert scale was used to rate the importance of 91 job tasks. McKillip [9] also described another job analysis study conducted for a Master's in Library Science (MLS) degree, the goal of which was to find out if further training in the form of certification was needed to meet the challenge of keeping pace with library work. A nine-point Likert-type rating scale was used to measure the importance of the job tasks needed for their professional work. The scale was labeled: (1) Not at all, (3) Minimally, (5) Somewhat, (7) Very, and (9) Extremely.

Research Design. The Delphi technique is considered to have great potential for use in problem solving, decision making, strategic planning, and curriculum development. The Delphi methodology allows collection of opinions from geographically dispersed experts [9]. The benefits of obtaining accurate and thoughtful consensus from a group of geographically dispersed experts outweigh the time required to perform a Delphi study relative to a one-shot survey.

Research Methodology

A modified Delphi technique with qualitative and quantitative components was used to survey the participants and achieve the objective of this study. The Delphi technique utilizes a panel of experts to achieve group consensus on a particular topic through a series of carefully designed sequential questionnaires interspersed with feedback from the participants. The Delphi methodology used for this study consisted of a Web-based pre-Delphi study and three rounds of email-based and paper-based questionnaires.

Using the results of a review of literature and competency areas tested by the current lean manufacturing certification examination, an initial list of competency areas was presented to a sample of participants via a Web-based survey during the pre-Delphi round. The questionnaire in the pre-Delphi round was quantitative in nature, with additional spaces provided to the participants to include any additional competency areas that they believed to be important to include in the lean body of knowledge.

Responses to a set of demographic questions in the pre-Delphi survey were used to select Delphi panel experts for subsequent Delphi rounds. In Round One, the panel members were asked to provide both quantitative and qualitative feedback on the competency areas. During the second questionnaire round, an analysis made of the first round's results was provided for reference. Qualitative feedback obtained from the open-ended questions for each response was provided verbatim along with possible additions or modifications recommended from Round One. Similarly, in Round Three, an analysis made from Round Two was provided to the panel of members and final modifications recommended by them were incorporated.

Data Collection

The sample group used for this study was obtained by contacting the members of the Society of Manufacturing Engineering (SME) and the Institute of Industrial Engineers (IIE). Approximately 6,000 subjects with an email address were randomly selected from the SME database and IIE directory of members based on their interest in lean manufacturing.

Responses from 138 subjects were obtained from the pre-Delphi survey, out of which 102 Delphi panel members were selected for the first Delphi round based upon the following reported information, which is listed in order of importance: (a) commitment to serve on the Delphi panel, (b) self-rating of their expertise in lean (greater than or equal to 3 on the Likert scale), and (c) years of experience in lean. During Round One, the Delphi panel members who were selected to participate in the study but did not respond to the Round One questionnaire were contacted to verify whether they were interested in being a part of the study. Based on their responses, the Delphi panel was reduced from 102 preliminary members to 76 final members.

The pre-Delphi questionnaire consisted of: (a) an email message that was sent to the participants signed by the researcher and manager of certification from SME, (b) an informed consent form, (c) demographic questions, and (d) competency areas for rating.

The pre-Delphi questionnaire also contained an open-ended item that allowed the respondents to suggest additional competency areas other than those already mentioned in the questionnaire. These additional areas were included in the Round One, Two, and Three Delphi questionnaires, with comments and ratings by the panel experts.

The participants were asked to judge the importance of a particular competency area for the lean manufacturing exam using a five-point Likert-type scale. The following criterion of importance was assigned to the responses provided on the questionnaire given to them, along with an example of how to respond: 4 = Extremely important, 3 = Very important, 2 = Important, 1 = Of little importance, 0 = Not important. A dichotomous type question of "yes" or "no" was asked to identify the necessity for each specific competency area to be included at each lean certification exam level.

Data Analysis

After searching the literature and examining the data analysis methods used in different fields of study, the methodology utilized by Tillman [10] and Shah [11] seemed to be most applicable to this study. The additional competency areas suggested by participants in the pre-Delphi survey were analyzed and added to the Round One questionnaire under each domain, based on the researcher's judgment and analysis. In Round One, each of the competency areas was given modal and percent of concurrence scores from the pre-Delphi survey results. Data analysis during the first round of the process was conducted once all Round One feedback was returned. Each of the competency areas rated in Round One of the Delphi study was given modal and percent of concurrence scores, which were then reflected in the Round Two Delphi questionnaire. Additional comments from Round One that addressed more general concerns about the study were provided in the "Round One Results" document. Data analysis of Round Two was conducted in the same manner as in Round One. Similarly, Round Two results were reported in the Round Three questionnaire. Data analysis of Round Three was performed in the same manner as for Rounds One and Two.

To obtain convergence of opinion, the mean of the standard deviation for each round was calculated. A decrease in the mean standard deviation value indicated a greater convergence of opinion among the panelists. On the basis of the standard deviation scores, the following four categories of the prioritized list were formed (see Table 1): (a) higher mean score, lower standard deviation, (b) higher mean score, higher standard deviation, (c) lower mean score, higher standard deviation, (d) lower mean score, lower standard deviation. A decision of high and low mean and standard deviation was based on the range of results obtained in each category of analysis. An approach followed by Shah [11] and Tillman [10] was followed to determine a cut-off point for defining high and low mean, and high and low standard deviation. Higher and lower values of standard deviations were determined based on the median value of standard deviation under each domain.

Category I indicated that its competency areas are considered to be important for candidates to know for the lean certification exam, and there was relative agreement among panel members on their importance. Category II indicated that its competency

areas are also considered to be important for the certification, but there was less relative agreement among panel members on their importance.

Table 1. Matrix to Portray Categories for Prioritization

	Standard Deviation in Scoring Low ⟷ High	
High ↑ Mean Score ↓ Low	I Higher Agreement of Greater Importance	II Lesser Agreement of Higher Importance
	IV Higher Agreement of Lower Importance	III Lesser Agreement of Lower Importance

Category III indicated that its competency areas were less important for a lean certification exam than competency areas in Categories I and II but that there was less relative agreement among panel members concerning the competency areas' levels of importance. Category IV indicated that those competency areas are also considered less important for lean certification than competency areas in Categories I and II and that there was relative agreement among panel members on their lower levels of importance.

Results

The demographic information collected in the pre-Delphi round indicated that the majority of the experts were in the age range of 35–54, with most having a Master's degree. About 44 percent of the respondents possessed at least one professional certification or license. The majority of them were either at a senior management or mid-management level, while only 5 percent were college or university faculty. Almost 17 percent of the panel members were located outside the United States. Their self-rating of the level of expertise in the field of lean manufacturing ranged from medium to very high, with the majority rating themselves as having a high level of expertise. Moreover, a large number of experts had a minimum of 6–10 years of experience related to lean.

The panel of experts participated through three iterations of Delphi questionnaires in both mail and electronic format, rated competency areas, and offered many valuable comments. Additional competency areas suggested by the pre-Delphi study were added to the Round One questionnaire. The three rounds of the study had response rates of approximately 73 percent, 79 percent, and 75 percent.

Table 2 contains results based on the additional questions asked regarding the importance and overall quality of the study in the Round Three questionnaire. The majority of the Delphi panel experts indicated that the results of this study were either of very high or high importance to the field of lean manufacturing. Moreover, predominant responses for the overall quality of the study ranged from very high to high.

Table 2. Results on Importance and Overall Quality of the Study from Round Three

	Very High 5	*High 4*	*Medium 3*	*Low 2*	*Very Low 1*	TOTAL
Importance of the results of this study to the field of lean manufacturing	36%	*57%*	2%	3%	2%	53
Overall quality of study	32%	*51%*	15%	2%	0%	53

Samples of qualitative responses obtained on the importance and/or quality of the study are listed below:

- *"As a lean practitioner over the past six years, not having a valid certificate demonstrating proficiency in lean is a drawback. The industry needs an effective method to document and certify individuals, and this study will enable a robust standard to be set."*
- *"This study was well developed and was very comprehensive. This is a good model for overall business planning and execution."*
- *"This study is an important step in validating BOK. I don't know how influential the survey group is or how willing they are to use your findings. Good luck on your paper."*
- *"My interest in this survey/study has greatly increased since my professional developmental goal for this year is to obtain a lean certification!!"*
- *"I feel the study was prepared very well and complete."*
- *"The study is the most comprehensive that I have ever seen in my career. I hope that it will serve to standardize and further lean principles beyond the current narrow minded focus of cost cutting ..."*

A list of prioritized competency areas delineated for the Silver level of the lean certification examination, based on mean and standard deviation scores, is given in Table 3. The competency areas have been grouped under each domain and are categorized by low and high standard deviations. The competency areas in bold with asterisks (*) represent high mean and low standard deviation (higher degree of consensus among panel members), and those not in bold represent lower degree of agreement among panel members with either high or low mean values. Y% represents the percentage of "Yes" responses obtained from the "Necessary for Certification Exam?" question.

Table 3: Prioritized List of Competency Areas for the Silver Level of Lean Certification

Competency Areas	Mean	SD	Y%
I. ENABLERS FOR LEAN			
***1.1.4. Principles of Lean Leadership**	**4.00**	**0.000**	**100.0**

***1.1.5. Lean Corporate Culture**	**3.96**	**0.192**	**100.0**
***1.2.6. Ergonomic, Clean and Safe Work Environment, and Results**	**3.95**	**0.225**	**100.0**
***1.2.3. Teamwork**	**3.89**	**0.420**	**100.0**
***1.2.2. Employee Training and Development**	**3.09**	**0.391**	**100.0**
1.2.1. Principles of Empowerment	3.07	0.457	98.2
***1.1.1 Business Vision, Mission, Values, Strategies and Goals, Including Resource Allocation**	**3.04**	**0.186**	**98.0**
1.1.3. Long and Short-term Planning	2.96	0.376	98.1
1.2.4. Suggestion/Feedback/Appraisal System	2.96	0.466	96.4
Motivation Theory	2.74	0.695	85.7
Socio-technical Systems	2.53	0.570	71.4
1.1.2. Respect for Humanity and Social Responsibility	2.12	0.734	25.9
1.2.5. Employee Turnover, Absenteeism, and Compensation	2.02	0.582	17.9
II. LEAN CORE OPERATIONS			
***2.4.3. Cellular and Continuous Flow**	**3.98**	**0.134**	**100.0**
***2.4.2. Just-in-time Operations**	**3.98**	**0.135**	**100.0**
***2.4.4. Lean Tools for Continuous Improvement**	**3.96**	**0.186**	**100.0**
***2.4.1. Systematic Identification and Elimination of Waste**	**3.95**	**0.229**	**100.0**
***2.2.1 Product Design and Development**	**3.04**	**0.462**	**96.4**
Facilities Design and Layout	3.02	0.668	94.6
2.1.1. Operational Vision and Strategy	2.96	0.462	100.0
***2.3.1. Suppliers**	**2.93**	**0.417**	**96.4**
***2.3.3. Distribution and Transport Alliances**	**2.82**	**0.386**	**90.9**
Quantitative Decision-Making Techniques	2.80	0.621	79.6
Six Sigma/Problem Solving Techniques	2.75	0.640	83.6
2.3.2 Customers	2.74	0.613	91.1
2.2.2. Product Market Service	2.68	0.631	78.2
Simulation Technique	2.39	0.774	54.5
Optimization Techniques	2.07	0.704	32.1

Table 3 (continued): Prioritized List of Competency Areas for the Silver Level of Lean Certification

Competency Areas	Mean	SD	Y%
III. BUSINESS CORE OPERATIONS – SUPPORT FUNCTIONS			
***3.1.1 Administrative Vision and Strategy**	**3.09**	**0.342**	**100.0**
***3.1.2. Alignment and Systematic Business and Service Process Design**	**2.89**	**0.528**	**94.5**

Supply Chain Logistics	2.88	0.470	90.9
Lean Accounting	2.63	0.590	80.0
Materials Requirement Planning (MRP)/Enterprise Resource Planning (ERP)	2.39	0.596	83.0
IV. QUALITY, COST, AND DELIVERY MEASURES			
***4.2.1 Cost and Productivity Results**	**3.93**	**0.260**	**100.0**
***4.1.1 Quality Results**	**3.89**	**0.369**	**98.1**
***4.3.1 Delivery and Customer Service Measurement**	**3.79**	**0.456**	**98.2**
Quality Management System (QMS)	2.75	0.700	85.2
International Organization for Standardization (ISO) and Lean	2.27	0.674	67.3
V. BUSINESS RESULTS			
***Lean Business Metrics**	**3.02**	**0.551**	**98.2**
***5.1.1 Customer Satisfaction Results**	**2.88**	**0.470**	**92.7**
5.2.1. Profitability Measurement	2.77	0.577	88.7
Total Supply Chain Cost	2.77	0.632	81.8

The prioritized list of competency areas obtained for the Silver level examination indicates the important areas to be included in the BOK of the lean manufacturing certification exam. A curriculum model can be designed based on these competency areas for a graduate-level program in lean manufacturing.

For example, the BOKs for CMfgT and CMfgE certification examinations [10] are widely used as guidelines for undergraduate and graduate manufacturing curriculum development; these exams are then taken by students, and their grouped performance results are used as external measures for program assessment and ABET accreditation evaluation. Likewise, the curriculum for the Engineering Management (EM) program at Eastern Michigan University (EMU) is based on the body of knowledge for the CEM examination; students take the CEM exam just prior to graduation, in the program's capstone course. Similarly, the curriculum for the Lean Enterprise Systems track of EMU's EM program will be based on the body of knowledge for the lean certification exam [12], and students will take the Silver lean certification exam in the lean track's capstone course.

Professional certification is recognition of competency in a professional discipline and is valued and/or expected by employers. Most students appreciate the opportunity to gain certification as part of their graduate masters program, as well as the benefits that certification provide when seeking employment or professional advancement. The competency areas delineated in the BOKs for certification define a professional discipline and are therefore quite helpful and practical to use when defining the curriculum for a graduate program in that professional discipline [5].

Conclusion

This role delineation study was conducted to refine the body of knowledge for the SME/AME/Shingo lean manufacturing certification examinations. A Delphi technique with both qualitative and quantitative components was used to collect data and obtain feedback and suggestions from experts in the field of lean manufacturing. A convergence of opinion on the competency areas provided the basis for validating the body of knowledge for Bronze, Silver, and Gold levels of lean certification examinations.

It is noteworthy to recognize the high level of professionalism of the panel of experts that participated in the study, as exemplified through their prompt and thorough responses. The comments and ratings provided by these experts were a good indication of the fact that the study was of high importance for the lean manufacturing discipline and that it was also of high quality. A prioritized list of 42 competency areas that emerged from the study was organized as a BOK and grouped into five major domains: (a) Enablers for Lean, (b) Lean Core Operations, (c) Business Core Operations – Support Functions, (d) Quality, Cost and Delivery Measures, and (e) Business Results. This BOK can serve as a model for developing a graduate level curriculum in lean manufacturing.

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