A new master degree program in lean manufacturing technologies

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Abstract. Increasing productivity and operational effectiveness can be realized by professional managerial approach. The article considers the current lean manufacturing and production management education providers and find the necessary points for successful operation management realization. Also it is proposed the interaction between the university and industrial partners in order to build and update the education content, participate in the classes and enrich them with industrial cases and guarantee the future career for the students. Lean manufacturing education is based on DMAIC methodology and proper using of Quality Management methods for continuous improvement of organizations. This long-term program provides professional growth for the employees and build their improvement projects sustainable.

Introduction

Manufacturing system is a system which combines people, information, methods and equipment to converse production inputs (raw materials, customer orders) into the outputs (final products for the customer). Continuous improvement (CI) of manufacturing system is the aim of any business and it helps to better compete in today's global market [1-2]. In order to become a world-class manufacturing system, there is a need for professional operational managers who are able to handle necessary changes to existing cultures, business operating systems and operational practices [3]. World-level manufacturing systems developed their own manufacturing system approaches, such as 8D by Ford, Toyota Production System, 3R5S by Hyundai and other.

ETU LETI Department of Management and Quality Systems (MQS) provides the courses of Quality Management more than 20 years. This experience shows the need for regular industrial partnership for internship organizing, classes participating and learning material updating.

The current MQS educational programs are mostly focused on quality management, but manufacturing system improvement contains more issues. Thus the MQS team created a new Lean Manufacturing Technologies (LMT) Master's Degree Program to provide a combined education in quality management, economics and human resource management using lean

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principles. This concept provides a system thinking about the company issues and interdisciplinary approach needed for effective change management [4].

The focus of this paper concerns the development and implementation of this project by industrial/academic partnership.

The subject overview

The main concept of Lean Six Sigma (LSS) is determine and any types of waste and increase a process capability [1; 2; 5-7]. Lean manufacturing contains general concepts, such as value for customer, waste types, reduction of all resources used in the business processes. All the process activities are divided into value-added and non-value-added. Continuous improvement is essential part of lean thinking, which underlines the necessity of improvement cycles and proper process engineering. A systematic methodology of waste recognition and elimination production costs reduction, productivity increase and reduced production lead time. Dankbaar (1997) mentioned, that "contrast to conventional mass manufacturing, lean manufacturing can produce a wider variety of products at cheaper prices with higher quality while using less of each input: fewer people with reduced space, smaller investment, as well as shorter development timeframes" [2].

Lean manufacturers pay a great attention for training, development and idea gathering. Multitalented staff meets the diverse needs of customers providing better services with help of standardization and quickly implemented innovations.

In the Figure 1 there is a representation of the Continuous Improvement Framework as a part of the company's LM system [2].

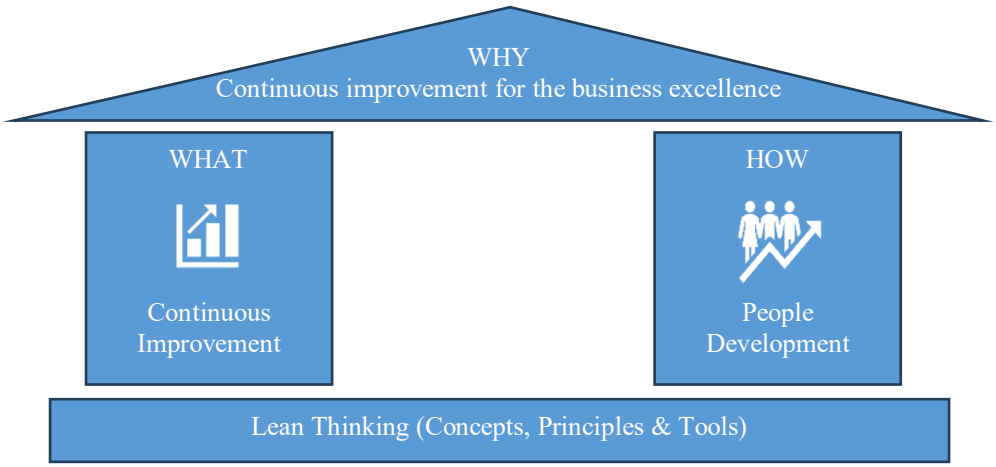

Fig. 1. Continuous Improvement Framework in Lean Manufacturing System.

Lean manufacturing and Quality management have the variety of tools. Implementing of the tools depends on the problem investigated and the qualification of team members (Table 1). Voehl (2014) listed the tools and methods for process acceleration. The approach breaks organizational restrictions and proposes cross-functional teamwork with help of statistical and non-statistical methods.

Table 1. Lean Manufacturing and Quality Management Tools and Methods

Non-statistical	Statistical
5S Benchmarking of Processes Bureaucracy Elimination Conflict Resolution Critical to Quality Cycle Time Analysis and Reduction Fast-Action Solution Technique Just-in-Time Matrix Diagram/Decision Matrix Measurements Organizational Change Management Pareto Diagrams Prioritization Matrix Project Management Quality Function Deployment Reliability Management System Root Cause Analysis Scatter Diagrams Selection Matrix (Decision Matrix) SIPOC Diagram Strengths, Weaknesses, Opportunities, and Threats Takt Time Theory of Constraints Tree Diagrams	Analysis of Variance Attributes control charts Binomial distribution Chi-square test Box Plots Confidence Intervals Data Transformations Design of Experiments Measurement Systems Analysis Method of Least Squares Multivari Charts Nonparametric Statistical Tests Populations and Samples Probability theory Process capability analysis Regression Analysis Rolled-Throughput Yield Statistical process control Taguchi Method

International standards ISO 18404:2015, ISO 13053-1:2011 and ISO 13053-2:2011 are the frame of statistical methods and lean manufacturing tools and competences needed for successful CIs. Tools mentioned in the standards can be learned through different education techniques. In [4; 8; 9] there are levels of lean manufacturing specialists so the education provider have to help the customers to train the personnel with relevant tasks for future projects. Recently there are various organizations provide LSS trainings and consulting (Table 2).

Lean manufacturing in the Higher Education can be represented as a separate course [3], interdisciplinary course or as an educational program (Table 3). The University uses industrial cases for round up students' mind and fulfil the theory with real cases, but the students are not involved in the real optimization project.

Table 2. Lean Manufacturing training courses.

Service	Provider	Course type	Issues
Fundamentals and tools of lean manufacturing	Incorporate training centers	Short-term courses within the organization, communication with the company's strategy	The need for external support, industry specifics
	Training centers	Short courses, retraining	Need for contractor quality

Lean manufacturing application	Consulting	Short courses and methodological support for the implementation of point improvements	assessment, short projects
Professional education in lean manufacturing	High Education Institutions	Master's Program	Lack of completed projects experience

Real industrial practice is represented in the interdisciplinary course of Oakland's Pawley Institute [3]. During the course, the Industrial partner gives the real data and tasks for both the whole cohort investigation and smaller specific team tasks. The teams have an opportunity to enter the industrial partner plant and get the necessary data directly from the "gemba" (the place in the company where the value for customer is being created). Students' feedback has shown a great experience about real project participation and a need of prerequisite Lean Principles and the basic operational management macroscope courses. The company's feedback was also positive and there is a long-term partnership has been created.

Table 3. Lean Manufacturing education in High Education Institutions.

Separate courses	**Interdisciplinary courses**	**Educational program**
Lean manufacturing basics Quality management tools Lean manufacturing tools LSS DMAIC courses (Yellow Belt, Green-Belt, Black Belt)	The Industrial partner gives the real data and tasks for both the whole cohort investigation and smaller specific team tasks. Project task contains multiple disciplines	Production management Quality management Operational management Management of transformation

There is a growing interest in lean manufacturing and quality management education, but Higher Education needs more industrial/academic cooperation.

Industrial partners handle internal education courses for the employees. They are represented as introduction programs for all the new-hired employees, specific functional trainings and the courses for leaders. These programs gives the knowledges specific for the industry, but there is a great necessity to combine industrial best practices and implement them to the other spheres with help of Academic resources.

Problem statement and methodology

The purpose of the study is to consider the current situation of lean manufacturing training courses and create the model of industrial/academic cooperation for the new Master's program of Lean Manufacturing Technologies. The education program is based on approaches of Quality Management, Lean Manufacturing, Economy and Human Resource Management. These disciplines give a structured vision of change management and build the readiness for cross-functional teamwork. Real industrial projects are handled during the internship so the students have the access to the actual industrial cases.

The research results

1.1 ETU LETI LMT Program

1.1.1 ETU LETI Competence Center for Lean Manufacturing

Competence Center for Lean Manufacturing in High-tech Industries and the Department of Management and Quality Systems are the parts of ETU LETI which deal with issues of production management, quality assurance and development of manufacturing systems.

The opening of the ETU LETI LMT Program will provide an increase in the knowledge base and strengthen the position of the University in the scientific community considering the experience of quality management and lean manufacturing tools implementation and their effectiveness. A feature of the Competence Center is its practical orientation. Simulation games and trainings include practical problem situations that need to be resolved in the learning process. Competence Center provides relevant courses for Engineering students as the expansion of the University's courses and increases the loyalty of undergraduate students and their desire to stay in the Master's Degree Programs, as well as attract third-party students.

1.1.2 The LMT Program concept

2-years education course gives the systemized vision of the continuous organizational improvements. The LMT Program proposes an employment for all the students during the education, which makes the program attractive for students.

The LMT Program involves the implementation of manufacturing system development projects of the organization according to a pre-approved technical task. So, in addition to a loyal employee, the organization receives a portfolio of completed improvement projects and an assessment of their economic effect.

Now the LMT Program is planned only in full-time format in cooperation with local organizations of St. Petersburg and the Leningrad region. Further scaling is possible after the local experience and a positive feedback.

During the educational period, the teacher-curator monitors the progress of students, and the learning process takes place both on educational examples and on the case studies of partner organizations. This is how students develop a portfolio of complete improvement projects and exchange experience with each other.

1.1.3 Application requirements

In order to successfully launch the LMT Program, there are requirements for the applicants:

1) employment in positions responsible for processes of manufacturing system (considering offers of candidates from an industrial partner or a competition for bachelor's/specialty graduates);

2) understanding the basics of the industry and production technology (operational experience in the industry, full-time or internship);

3) ready to lead change projects (any experience of teamwork, project activity, self-presentation, understanding of the role of a change leader is evaluated).

Industrial/academic cooperation has to be well-planned and structured. Oakland's Pawley Institute [3] uses the following criteria for selecting a company partner for the lean course project:

1) A receptive management and workforce that will allow student teams access to shop floor processes, material flow, information systems and data in addition to allowing minor disruptions to normal work activities.

2) Existing opportunities to apply lean concepts and practices based upon the current state of the company's lean transformation, work activities and processes.

3) A desire to participate in a win/win relationship based upon the students learning more about lean through real world application and the company benefiting from the close examination of its current state processes as well as from the ideas and recommendations for improvement generated by the student teams.

These criteria are relevant for the considered ETU LETI Lean Manufacturing Technologies Master's Degree Program. Additionally the LMT Program ask from the industrial partner to provide a part-time position for the student. It would help both to gather the data for educational tasks and motivate the student to stay in the company.

One more criteria is a readiness of a company management to participate the LMT Program Academic Council. ETU LETI Lean Manufacturing Technologies Master's Degree Program has to be continually updated with ongoing industrial projects, actual data and real operational projects' feedback, so the industrial representatives are invited to special team meetings and they have an opportunity to enrich the LMT Program with their experience.

Interaction with partner organizations takes place in the form of project (Table 4).

The central point of the LMT Program is the Technical Task from the industrial partner. The document contains the tasks and the company issues and it is communicated with both the University and an applicant. If the Technical Task is approved by three parties, there is a guarantee company readiness for manufacturing system improvement for the next two years.

Table 4. Roles in the LMT Program

Role	**The head of the organization/involved department is the sponsor of the projects**	**Scientific supervisor/ mentor**	**LMT Program Students**
Tasks	Sets the primary Technical Task Coordinates the implementation and provides resources for the implementation of the Technical Task Accepts project results Gives feedback on projects and interaction experience	Participates in the initial statement of the Technical Task. Advises undergraduates, monitors their progress Provides in-depth expertise (disciplines, consultations, organizes group discussion of areas of science) Investigates feedback from the graduates and the partners, designs changes to the LMT Program	Independently explores the problem area and its organization. Designs, verifies and organizes the implementation of the manufacturing system change projects. Reports the progress. Interacts with the group (cross-control of the students)

The LMT Program contains research, project and internship activities. Project-based education makes the students more self-organized, focused on the tasks and frames and lets the students feel their role in real projects as a change manager (Table 5).

Table 5. The LMT Program Structure

Task	1 Semester	2 Semester	3 Semester	4 Semester
Research	**Industrial context**. Determine current manufacturing system issues	**Manufacturing system processes,** their effectiveness and problems	Implement QC and LM tools, effectiveness and influence review, **develop recommendations for the industry**	
Projects	**MS development strategy** Find the opportunities to grow	- Problem solving **(8D)** - Statistical methods of process improvement **(DMAIC)** - Personnel involvement		
Practice	**Company system analysis**	**Projects implementing and feedback analysis**		

The LMT Program provides the following learning outcomes:

- portfolio of implemented change projects (8D, DMAIC, personnel involvement);
- for Graduates: professional experience (2 years), deep understanding of organizational development tools, subjectivity and self-organization, responsibility for solutions; professional focus in the problem area, a personal experience in project implementation;
- for the University: building up the knowledge base on quality management and lean manufacturing, testing hypotheses and models in practice, increasing the expertise of teachers and the attractiveness of educational programs, a portfolio of project cases;
- for an Industrial Partner: a motivated leader of changes in the staff of the organization for at least 2 years; professional support according to the LMT Program; the economic effect of the implemented change projects.

5 Conclusion and future work

The LMT Program is aimed at cultivating a professional manager of changes in the manufacturing system by conducting research and implementing projects for the development of a real organization using approaches of economics, quality management, lean manufacturing and management competencies.

Industrial/academic cooperation during the LMT Program can be organized with three steps:

1)Testing the entering criteria (company readiness);

2)Set the primary Technical Task and approve it with the student and the University;

3)The company feedback about the LMT Program syllabus and project experience.

This communication cycle helps to successfully launch and maintain the considered LMT Program.

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