How Green Is Your Black Belt?

Dick Theisens

Symbol BV
Institutenweg 26, 7521PK Enschede, The Netherlands
dick.theisens@symbolbv.nl, www.lssa.eu

Abstract. If your company wants to stay or become more competitive it is important to constantly focus on the main elements Time, Quality and Costs. Applying both Lean and Six Sigma is the right approach for achieving this goal.

Lean Six Sigma is a management philosophy. You find this philosophy explained in many books and articles. The top management decision that Lean Six Sigma is the way to go, is key for success. But after this decision you have to deploy it. Then you will realize implementing Lean Six Sigma is more than a philosophy. It is also about applying the enormous number of tools in the right way. Especially Six Sigma contains many sophisticated analytical and statistical tools. On top of that is the Human Factor that, especially in Lean transformation, is also a key element.

Within Six Sigma employees can be trained at various belt levels. Nowadays these levels are also used to appoint how experienced one is in applying Lean methodology. These levels are called Master Black Belt, Black Belt, Green Belt, Orange Belt and Yellow Belt. Although there are several companies worldwide that train in Lean and Six Sigma, there is no common standard in what elements should be applied within a certain belt. As a consequence the Belt-levels can mean many things. You can train your employees or hire people that call themselves Green Belt or Black Belt, but how do you know this person has the skills you are looking for? How 'Green' is your Black Belt ?

To meet this problem, the LSSA was established in September 2009. LSSA stands for 'Lean Six Sigma Academy'. The LSSA main objective is to establish a common European certification standard by developing skill sets, training material and an exam portal. People will be able to apply for a European certificate for the above mentioned levels. Four Skill sets have been derived that exactly describe which of the overall Lean Six Sigma tools are expected to be part at a certain Belt level. The ASQ - Body of knowledge [5], [6] have been taken as a baseline and have been updated according the latest insights.

1 Origins of Lean Manufacturing

The first person to truly integrate an entire production process was Henry Ford by lining up fabrication steps in process sequence, using standardized work and interchangeable parts, which he called Flow production (1913). The problem with Ford's system was its inability to provide variety. The Model T was limited to one color (Black) and it was also limited to one specification so that all Model T chassis were essentially identical up through the end of production in 1926.

A. Riel et al. (Eds.): EuroSPI 2010, CCIS 99, pp. 257–267, 2010.

Kiichiro Toyoda, Taiichi Ohno, and others at Toyota looked at the Ford's situation in the 1930s, and more intensely just after World War II (1950). While Ford produced 8000 vehicles per day, Toyota had produced 2500 vehicles in 13 years. Toyota wanted to scale up production but faced a lack of financial resources for the huge number of inventory and sub assemblies they saw at the Ford's plant. It occurred to them that a series of simple innovations might make it more possible to provide both continuity in process flow and a wide variety in product offerings. Toyota developed the Toyota Production System (TPS). TPS borrowed Fords ideas but since they couldn't afford the huge inventories Toyota introduced its Just in Time (JIT) philosophy and the 'Pull Concept'.

A detailed description of the Toyota Production System and its 14 principles are described in the book 'The Toyota Way', (2004) [Jeffrey K. Liker, PhD], [1]. The thought process of Lean was thoroughly described in the book 'The Machine That Changed the World '(1990) [2] and in a subsequent volume, 'Lean Thinking' (1996), [James P. Womack and Daniel T. Jones], [3] in which the described the five Lean principles.

1. Customer Value	Specify the value desired by the customer
2. Waste elimination	Identifying and eliminating non-value added activities
3. Continuous flow	Make the product flow continuously
4. Pull instead of Push	Using pull between steps where continuous flow is possible
5. Continuous Improvement	Manage toward perfection

Toyota became in 2008 the world's largest Automaker in terms of overall sales. This continued success has over the past two decades created an enormous demand for greater knowledge about Lean thinking. There are literally hundreds of books and papers and numerous other resources available to this growing audience.

2 Origins of Six Sigma

Six Sigma is a long-term, forward-thinking initiative designed to fundamentally change the way corporations do business. It is first and foremost 'a business process' that enables companies to increase profits dramatically by streamlining operations, improving quality, and eliminating defects or mistakes in everything a company does. While traditional quality programs have focused on detecting and correcting defects, Six Sigma encompasses something broader: It provides specific methods to re-create the process so that defects are significantly reduced or even prevented at all [4].

The journey began at Motorola in 1979 when executive Art Sundry's stated in a management meeting, "The real problem at Motorola is that our quality stinks!" Facing stiff competition by Japanese manufacturers, Motorola began its search for ways to eliminate waste in its processes. Two Motorola engineers Bill Smith and Mikel Harry were credited for their pioneering work on defects, incited significant debate within Motorola on the process of finding and fixing defects. (first published in 1985). Their work on process capability, tolerance, critical-to-quality characteristics and design margins laid down much of the foundations of what today is called Six Sigma.

Recognizing a link between fewer defects and lower costs, Motorola set out to incorporate this into their manufacturing processes that was called 'Six Sigma'.

Motorola's Six Sigma quality program was so radical that it forced managers to think about the business differently. Applying these concepts to Motorola's electronics manufacturing delivered more than $2.2 billion in benefits within four years and $16 billion within 15 years. Motorola's CEO Bob Galvin cited the work of Bill Smith and Mikel Harry in achieving these benefits.

One of the companies that embraced the Six Sigma philosophy was General Electric. Jack Welch was told that Six Sigma could have a profound effect on GE quality. Although skeptical at first, the GE Chairman initiated a huge campaign called 'the GE Way'. He made an official announcement launching the quality initiative at GE's annual gathering of 500 top managers in January 1996. He called the program 'the biggest opportunity for growth, increased profitability, and individual employee satisfaction in the history of our company'. He has set itself a goal of becoming a Six Sigma quality company producing nearly defect-free products, services, and transactions, by taking quality to a whole new level. Welch intention was to infuse quality in every corner of the company. Layer on he called Six Sigma 'the most difficult stretch goal', but also 'the most important initiative' GE had ever undertaken. General Electric saved more than $12 billion with Six Sigma in the first five years after implementation.

In the last couple years the Lean and the Six Sigma philosophies are combined to Lean Six Sigma, with a combined set of tools and the common approach of reducing lead time and operational costs, and improving quality.

3 Applying Lean Six Sigma

World Class Performance is about developing and producing products and services that are the best in the world. One can become 'World Class' by performing at Operational Excellence and developing new products that exceed customer expectation. Operational Excellence is about continuously supplying products and services at the highest quality at lowest cost and at the right moment. This require a focus on producing products cost-efficient and without failures.

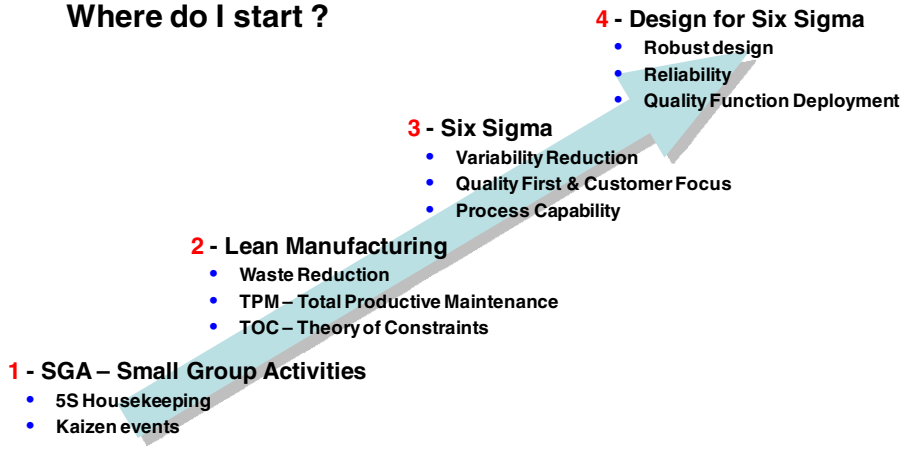
The first level of achieving World Class is organizing the work environment to realize a clear overview of activities and performance. It is also about a professional presentation of the facility. This can be compared by eating in a restaurant. Do you want to eat in an environment which is dirty, disorganized and where the cook has to search for the right ingredients? It is the same for a working environment. Customers expect their products are treated with the outmost care and people are performing the activities in a structured way. Realizing an organized environment can be achieved by applying '5S', which stand for Sort, Straighten, Shine, Standardize and Sustain. An organized environment is the starting point for all improvement activities. You need to get a structured environment first before you employ other methods and tools.

The first level is also about involving operators in quality and problem solving, instead of staff and indirect employees doing this. People at the work floor know very well how problems can be prevented and how operations can be improved. The problem is that very often they are not challenged and supported in these kind of activities. Getting a cooperative organization where the work floor is involved in continuous improvement can be achieved by Kaizen or SGA (Small Group Activities). 5S, Kaizen and SGA focus on the 'Gemba' (work floor).

The second level of achieving World Class is implementing Flow and Pull, and stopping operations when problems occur (called Jidoka). At the same time a focus in needed on reducing Waste. The way to realize this is a combination of TPM, TOC and Lean. TPM (Total Productive Maintenance) is a strategy to improve the effectiveness of the environment throughout the company and to reduce unscheduled downtime and quality issues caused by equipment. TOC (Theory of Constraints) is about identifying and eliminating the bottle necks in an organization. Lean Management aims on eliminating waste in every area of production including customer relations, product design, supplier networks and process management. Products and services with excellent quality have to be delivered when the customer wants (Just in time). Examples can be found in assembly operations but also in transactional processes like banking.

The third level of achieving World Class is applying Six Sigma by eliminating variability. Six Sigma is a rigorous and systematic methodology that utilizes information (management by facts) and statistical analysis to measure and improve a company's operational performance by preventing 'defects' and performing breakthrough improvements in solving problems. When procedures, operator training and simple problem solving tools are not adequate to solve a persistent problem, it is time for the Six Sigma approach with sophisticated analytical and statistical tools. For applying Six Sigma it is important to have stable processes. Therefore it is important to focus on an organized work environment and Lean first.

The fourth level of World Class is DfSS (Design for Six Sigma). Both Lean and Six Sigma have a focus on problem solving and prevention in the operations. DfSS has a focus in the development process. The goal of DfSS is to design products that exceed customer expectations; flawless product launch and a predictive reliability. DfSS is a systematic and rigorous methodology using tools, training, and measurements to enable the design of new products and processes that meet customer expectations at Six Sigma quality levels. DfSS has a focus on preventing problems rather than solving them by applying Six Sigma. Examples are found in product development in electronics and automotive industry.



4 Case Description – Laser Coding

In 2007 an Automotive supplier started a program to change over from labelling their products with a barcode to laser coding. For years their production location faced about 1% of yield loss on this label process which could not be reworked. The problems they faced were labels with bad coding, incorrect position or missing labels. The COPQ (Cost of Poor Quality) was around 300k$ per year.

Laser coding would solve these problems. The issue however was the readability of the laser coding. For almost two years several engineers tried to get a good and stable laser coding quality in place. Since they were not successful for such a long period, management requested the help of a Six Sigma Black Belt to lead this project. The Black Belt started a project that followed the DMAIC roadmap:

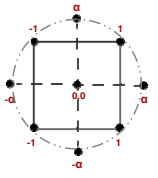
D	1 – Project Selection 2 – Project Management
M	3 – Define CTQ & Baseline Performance 4 – Validate Measurement Procedures
A	5 – Diagnose the current process 6 – Identify potential influence factors
I	7 – Define & Implement improvements 8 – Optimize & Verify improvements
C	9 – Improve control system 10 – Close out project

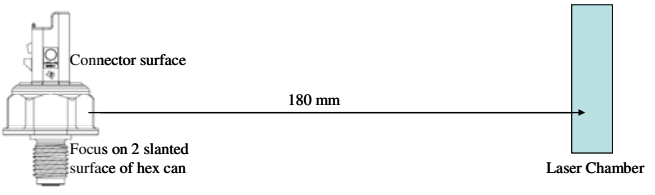
In the 'Measure' phase the first step is to make a CTQ-flowdown that is used to translate the external quality metric from the customer to an internal quality metric that can be measured in production by a label reader. The external CTQ [Good readability] was translated into an internal CTQ [Grade] and detailed out into four internal responses for the label reader [Contrast, Sharpness, Non-Uniformity, Print Growth]. A good performance of each of these four responses will result in a good 'Grade' performance. A good 'Grade' performance will result in a 'Good readability' and a satisfied customer. The internal CTQ 'Grade' and each of the four building blocks had to be measured. The next step then is to perform a Measurement System Analysis on the reader in order to see if the equipment is able to read accurate, consistent and reliable. A Gauge R&R% was conducted on the reader to verify this.

In the 'Analyse' phase a brainstorm session with engineering and the laser supplier was organized to identify potential Factors of Influence that might have an impact on the above mentioned responses. A screening DOE (Design of Experiments) has been performed to select the significant Factors of Influence. The experiment proved that Speed, Current, Frequency and Focal Distance all have an influence. Other potential factors were eliminated.

In the 'Improve' phase a second experiment was designed: a Box-Behnken Response Surface Model, which is an optimization experiment. For each of the four Factors of Influences the levels can be found below. Since the Response 'Grade' was ordinal, five repetitions were taken for each setting. The Response was calculated as the average for these five repetitions. Minitab software was used to set up the experiment and analyse the results.

Defined Factors of Influence		Lo	Hi
• Speed (mm/2)	Time the coding is made	750	850
• Frequency (kHz)	Frequency of the laser	17.5	22.5
• Current (Amp)	Current of the laser	25	27
• Focal (mm)	Distance laser optics and connector	179	181





After removing insignificant factors from the model, the Regression Model looked like the below figure (left). Also a contour plot was constructed for the response 'Grade' (right). The R-sq (Coefficient of Determination) shows that almost 82% of the total variation can be explained by the model. It means the model is Statistically Significant and conclusions can be derived based on this model.

Response Surface Regression: Grade versus Speed, Freq, Current, Focal

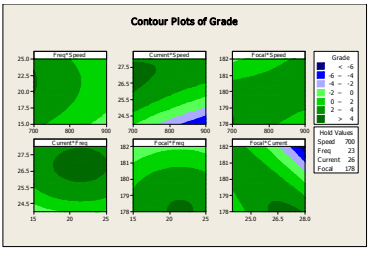
The analysis was done using coded units.

Estimated Regression Coefficients for Grade

Term	Coef	SE Coef	T	P
Constant	2.91206	0.1958	14.873	0.000
Speed	-0.01667	0.1225	-0.136	0.893
Freq	0.28333	0.1225	2.312	0.032
Current	-0.01667	0.1225	-0.136	0.893
Focal	-0.33333	0.1225	-2.720	0.013
Freq*Freq	-0.24362	0.1116	-2.183	0.041
Current*Current	-0.51862	0.1116	-4.646	0.000
Focal*Focal	-0.29362	0.1116	-2.631	0.016
Speed*Current	0.40000	0.1501	2.665	0.015
Speed*Focal	0.40000	0.1501	2.665	0.015
Current*Focal	-0.87500	0.1501	-5.831	0.000

S = 0.600286 PRESS = 27.5484

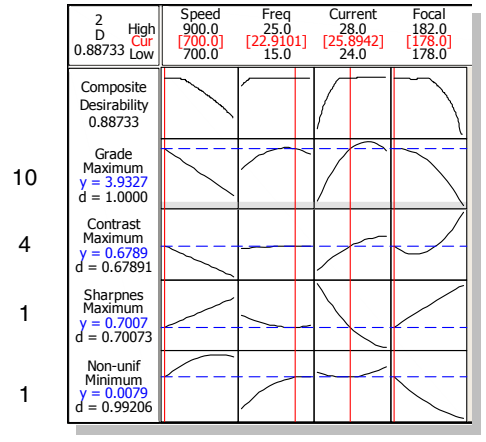
R-Sq = 81.79% R-Sq(pred) = 30.38% R-Sq(adj) = 72.68%



The next step in the improve phase was to use the response surface model to determine the optimum settings. Besides determining the optimum settings, there was also a focus to determine robust settings for the response 'Grade', in order to assure the readability will be robust over time and won't be sensitive for small variations from the Factors of Influence.

Using these optimum settings a verification run was performed with 100 devices to determine the capability of the process. For all 100 samples the maximum Grade of '4' was measured. Since the sample run showed no deviation it was not possible to construct a Process Capability Plot, which is normally done in this phase to determine the capability. In this case all samples had the maximum readability performance for 'Grade'.

In the 'Control' phase the process documents were updated and customers were informed on the changed coding. After submitting samples to the customers, they released the new coding and the process. Management appreciated and released the team.



Optimize

- When Current is reduced to 26, 'Grade' is getting more robust

Final Optimized Settings

- Speed 700
- Freq 23
- Current 26
- Focal 178

Robust Factors

- Frequency (& Speed)

The above mentioned project had actually a very short time line. Within two months the experiments were conducted and the coding process defined. It took almost a year to get customer approval to introduce the new coding. This is an example that changing processes is not only about conducting experiments and statistical analysis, but also about Project Management and Change Management. In some cases applying these Human Dynamics takes more time than applying the experiments itself. A Black Belt is a person that is able to apply both Lean tools, Six Sigma tools and Human dynamics. In this particular project only the Six Sigma tools were applied.

5 LSSA – Lean Six Sigma Academy

Although there are several companies worldwide that train individuals in Lean and Six Sigma, there is no global standard. Some people that followed a four days training and with little experience call themselves Black Belt and some Green Belt trainings do not include statistical analysis. Furthermore theoretical knowledge on methodology and tools is only one aspect. Applying these in real situations is a second aspect which is even more important. As a consequence the Belt-levels can mean many things. You can train your employees or hire people that call themselves Green Belt or Black Belt, but how do you know this person has the skills you are looking for? How 'Green' is the Black Belt that you want to hire?

In the US companies are referring to the standards of the ASQ – 'Body of knowledge' [5], [6]. In Europe there is no such like, although some training agencies refer to the 'Body of knowledge' as well. The shortcoming of the 'Body of knowledge' however is that it focuses on Six Sigma mainly rather than Lean. Most companies are not on the level of Six Sigma yet, so knowing how to apply Lean is important as well.

To meet these problems the LSSA was established in September 2009. LSSA stands for 'Lean Six Sigma Academy' and was raised by Symbol BV (the Netherlands), ROC of Twente (the Netherlands), INstitute Polytechnique de Grenoble (France), I.S.C.N. GesmbH (Austria), University of Twente (the Netherlands) and EMIRAcle (Belgium). Detailed information can be found at www.lssa.eu. The LSSA

main objective is to establish a common European certification standard by developing skill sets, training material and an exam portal. People will be able to apply for a European certificate for each of the four belt levels.

In Six Sigma one can be trained at a certain level, but generally spoken engineers are trained at a Green Belt level. Team members and work floor are trained at a Yellow Belt or Orange Belt level and Process Improvement project managers and senior engineers are trained at a Black Belt level. A Belt level is called a 'Job Role' within the domain 'Process Improvement'.

Job Role	**Vocational Education training**	**Adult Education / Function**
Yellow Belt	Initial VET secondary level	Team member, Operator
Orange Belt	-	Team member, Lean Facilitator, Supervisor
Green Belt	Higher Education	Engineer (Quality / Process / Design), Process owner
Black Belt	-	Senior Engineer, Project Manager, Management, Consultant

For each of the four Job roles Skill sets have been derived that exactly describes which of the overall Lean Six Sigma tools are expected to be part at a certain Belt level. A skill set is a set of 'Learning Elements' within eight 'Units'. The 'ASQ - Body of knowledge' for a Green Belt [5] and a Black Belt [6] have been taken as a baseline, and have been updated according the latest insights and Lean methodology. On top of the Green Belt and Black Belt, skill sets for the Orange Belt and the Yellow Belt have been defined. Another difference between the 'ASQ - Body of knowledge' and the 'LSSA Skill sets' is the structure. Each of the four skill sets within the LSSA have the same structure. The benefit is that you can easily compare what the difference is between a Yellow Belt and a Black Belt in the level of applying a certain set of tools (performance criteria).

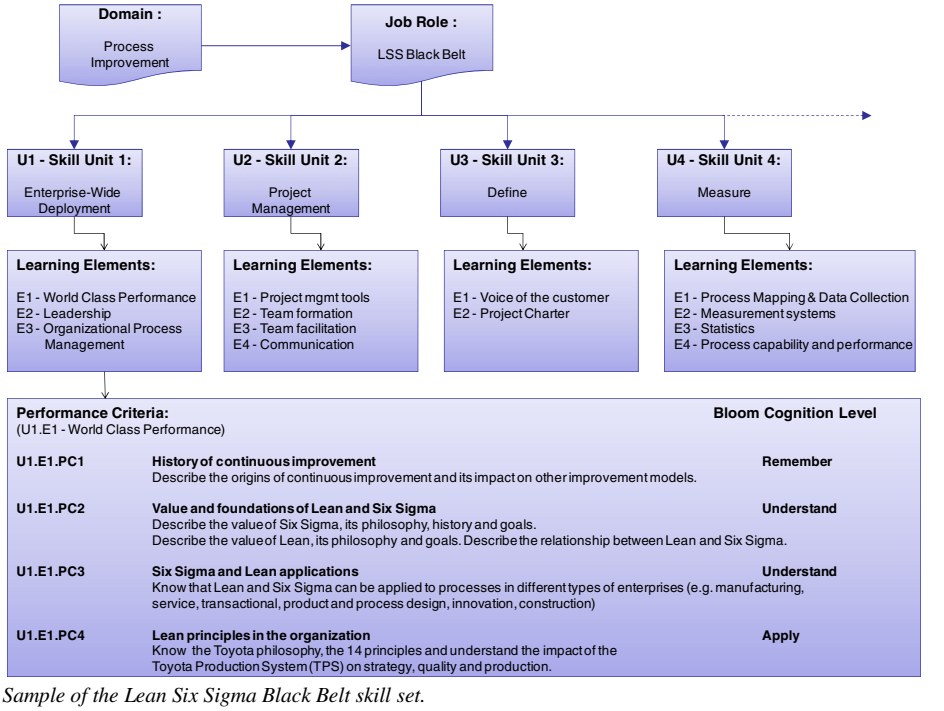
The Skill sets also mention how each Job role refers to the qualification levels within the NVQ (National Vocational Qualification standard) and the EQF (European Qualifications Framework). The NVQ is defined by European legislation and is used for comparability of vocational qualifications from different European countries. The EQF acts as a translation device to make national qualifications more readable across Europe, promoting workers' and learners' mobility between countries and facilitating their lifelong learning.

The structure consist of eight 'Units'. Each of these units is built up with a number of 'Learning Elements' that contains several 'Performance Criteria'. Each of the 'Performance Criteria' has a description and a cognitive level according Bloom [7] at which it should be applied.

The number of Performance Criteria, the description and the cognitive level are different for the four Belt levels. The number of Performance Criteria for a Black Belt is 117 and for a Yellow Belt 50. Below an example is given for the first Unit 'Enterprise Wide Deployment' and the first Learning Element 'World Class Performance'.

Unit	Learning Element
U1 - Enterprise Wide Deployment	E1 - World Class Performance
	E2 - Leadership
	E3 - Organizational Process Management
U2 - Project Management	E1 - Project management tools
	E2 - Team formation
	E3 - Team facilitation
	E4 - Communication
U3 – Define	E1 - Voice of the customer (VOC)
	E2 - Project charter
U4 – Measure	E1 - Process Mapping & Data Collection
	E2 - Statistics
	E3 - Measurement systems
	E4 - Process capability and performance
U5 – Analyze	E1 - Exploratory data analysis
	E2 - Hypothesis testing
	E3 - Analytical methods
U6 – Improve	E1 - Design of Experiments (DOE)
	E2 - Waste elimination
	E3 - Process Improvement Methods
U7 – Control	E1 - Statistical process control (SPC)
	E2 - Quality Assurance
	E3 - Sustain improvements
U8 - Design for Six Sigma (DFSS)	E1 - DFSS methodologies & Roadmap

List of Units and Learning Elements



Sample of the Lean Six Sigma Black Belt skill set.

Experienced Black Belts across Europe have been involved to define and review the Skill sets. Training material has been developed together with Initial VET, Universities and experienced Master Black Belts from Lean Six Sigma training institutes.

An exam portal will be set up in accordance with ECQA (European Certification & Qualification Association). The ECQA has been established through former LLP funded networks and currently certifies several professions in Europe [8]. Since the ability to apply the theory in practice is an important element of Lean Six Sigma, a panel will assess the projects. People that are trained can apply for examination and recognized with a Black Belt, Green Belt, Orange Belt or Yellow Belt certificate. It will also be possible to test people that are already trained and are working on process improvement projects in order to make companies more competitive.

6 Conclusions

More and more companies see the benefits of having employees trained in Lean Six Sigma in order to reduce Lead time, improve Quality of products and services and reduce operational costs. Applying Lean Six Sigma will help companies to stay or become more competitive.

Identifying at what level of expertise one is trained is difficult since people are trained by different agencies and companies. Theoretical training is not a guarantee for successful applying Lean and Six Sigma in real practise.

The LSSA skills sets clearly describe what elements and performance criteria are needed at a certain belt level. Assess employees through the ECQA framework can clarify the level of expertise in applying Lean and Six Sigma.

7 Abstract and Keywords

5S	Sort, Straighten, Shine, Standardize and Sustain
ASQ	America Society for Quality
DfSS	Design for Six Sigma
ECQA	European Certification & Qualification Association
EQF	European Qualifications Framework
JIT	Just In Time
LSS	Lean Six Sigma
LSSA	Lean Six Sigma Academy
SGA	Small Group Activities
TOC	Theory Of Constraints
TPM	Total Productive Maintenance
TPS	Toyota Production System
VET	Vocational Education training
NVQ	National Vocational Qualification standard (England, Wales & N. Ireland)
YB	Yellow Belt
OB	Orange Belt
GB	Green Belt
BB	Black Belt
MBB	Master Black Belt

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