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## Integrating Quality and Lean into a Holistic Production System

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### Abstract

Companies have for years tried to figure out how to consistently organize their business units for improving quality and efficiency and at the same time reduce costs and lead times. Toyota's production system (TPS) and its core principles have become the global benchmark. This system was developed throughout the 1950's and refined and improved to present. One of the main pillars is batch reduction – ultimately down to one-piece flow – which in turn leads to improved quality and flexibility. Quality at the source (QatS) was and still is a mantra at Toyota. However, we observe that in many firms lean and quality are frequently organized as separate and disintegrated departments and systems – often with overlapping goals. This paper reports on case studies done in three Norwegian manufacturing firms. The case studies aim to explore the relationship - or the lack thereof - between quality and lean as integrated parts of a holistic production system. Our three cases demonstrate that QatS may have something to do with maturity level of product and manufacturing technology, degree of standardization and stabilization, and the combination of explicit and tacit knowledge.

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Production system, lean, quality

### 1. Introduction

Increased globalization and competition greatly influence the way manufacturing companies in different parts of the world respond to pressures for improved quality and efficiency and reduced costs and lead times. The Toyota production system (TPS) is for many companies worldwide the benchmark. At the same time, quality systems from the ISO organization (i.e. ISO 9001, ISO TS 16949, 14001) have in many companies led to the emergence of separate business units and systems for tackling quality the "ISO-way". This "ISO-way" has not been fully integrated with the organizations' production systems, thus resulting in two separate systems for dealing with quality, efficiency, costs and lead times. Since the overall goals of the "Toyota-way" and "ISO-way" are overlapping, their integration into a holistic production system should in principle be

straightforward. However, there may be practical challenges, although the expected benefits from merging the systems together may be many: reduced bureaucracy, increased efficiency, improved quality, and hence increased profitability.

This article explores this issue in the context of three Norwegian manufacturing companies, all global market players, with extensive pressures to reduce costs in order to stay competitive in a high cost country. First, the article outlines the theoretical background of production systems. Second, the methodology is briefly explained. Thirdly, three industrial case studies illustrate how differences in maturity level influence the integration of quality and lean in production systems. Finally, conclusions and implications for practitioners and further research are presented.

### 1.1. Literature

Few researchers have tried to define production systems in general terms. Hubka and Eder [1] attempted to do so by presenting four subsystems; 1) the human system, 2) the technical system, 3) the information system, and 4) the management system, which all affect the transformation process from raw materials to products. A more recent description is provided by Clarke who claims that production systems represent the changing nature of the form and function of standardization [2]. By standardization he does not exclusively mean product standardization but also standardization of processes and work. Nevertheless, the history of production systems goes far back in time, and the military is often said to be a forerunner [3].

During the 18<sup>th</sup> century machines, jigs, fixtures and gauging systems developed towards part conformation and standardized interchangeable parts. Application of standardization and production systems went from military arms production to sewing, meat packing and to the early automotive industry [4]. Instead of individual freedom of the craftsman to design and produce, production engineers now made detailed drawings and guidelines, hence eroding the need for operators to think about work processes.

The next step was to fragment and standardize work tasks according to time and motion studies [5], leading to increased efficiency alongside improved product quality. Complexity was handled by subdividing the problem into minor tasks, easy to perform, which require a minimum of training and learning at the shop floor level. This approach separated thinking, doing, improving and performing, and assumed that workers were primarily driven by monetary incentives [6]. Mass production represented the first holistic production system, taking into account technology, processes, work standards as well as social standards regulating payment and working conditions.

The next major step in the evolution of production systems is the Toyota Production System (TPS). Toyota Motor Company was established in 1930, and this new company struggled through the 1930s by making poor quality vehicles based on primitive technology [7]. They decided to benchmark their processes against Ford and GM, but the implementation effort was put on hold because of World War II. The work continued in the 1950s [8], where Toyota found that the mass production system was a wasteful batch-production building up huge work-in-process inventory throughout the value chain - pushing products to the next process step [9]. This rigid and capital intensive system was seen as inappropriate for serving the dispersed, low volume market in Japan. In addition, the use of highly specialized workers at the American auto-companies, which were easy to replace, was an approach irreconcilable with Japanese work culture. This view emphasizes the human beings as the bedrock of all organizations in which solutions to problems are highly situation dependent. An example by Peter Drucker, referred to by Kamata [10], shows that it was a long way to go for the theory of collaboration; in the late 1940s General Motors introduced what was later called “quality circles” as a partnership between managers and workers to improve

products and processes, but the “United Auto Workers” (UAW) resisted and argued that even asking workers about their jobs was an unfair labor practice.

The TPS therefore proposes a different system of standards to achieve manufacturing efficiency with a minimum of resources through continuous improvement. The latter is regarded as major responsibility of the shopfloor worker. In the beginning of the 1950s American management practises, such as quality control, pioneered by Deming [11], were introduced and implemented. During the early 1960s Toyota introduced the first company wide total quality system, based on QatS and learning by doing principles [2]. QatS is today one of the main principles of the TPS, focusing on in-process quality and stabilization of processes [12].

The success of Toyota was soon recognized by other Japanese companies, and the spread of TPS to suppliers pushed towards formalization of the system [13] – resulting in the first publication by Ohno in 1978. This development- and formalization process continued throughout the 1980s and 1990s as Toyota expanded its operations globally. Finally, the MIT study concluded that the performance of TPS was unimpacted by culture, history, and social background, stating the new universal lean paradigm [14]. From a learning perspective TPS can be viewed as routinized learning capabilities applied at real life problem solving [15].

Another production system, known as the Volvo Uddevalla experiment, is based on principles of industrial democracy and teamwork. This system encourages workers to help each other to solve complex problems and smoothing out the work flow in parallel lines [2]. Placing human considerations in center, Volvo was aiming at increased flexibility, worker motivation and of course sustained efficiency and quality. The system demonstrated some promising features, but the factory closed down in a few years due to large variations in work methods and product quality [2].

Today most manufacturing companies build and develop their production system on the TPS. It is claimed that lean is not an option, it is mandatory for manufacturing firms operating in global markets [7]. Hence, a competitive factor is how companies manage to evolve from a company specific production system to a company-wide production system [16]. The latter raises many questions about degrees of freedom, and involvement in implementing such systems at different locations.

A core principle in TPS is QatS, achieved through the design of production systems that immediately uncover poor quality [17]. Combined with the emergent trends of company-wide production systems and compliance to ISO-standards, we propose the following research question:

*In which ways are quality (systems) integrated into holistic production systems in manufacturing companies?*

## 2. Method

This study has been part of a national research project concerned with work organization and operations management in Norwegian industry. Three case companies were investigated through assessments, observations, semi-

structured interviews, and reading of company documentation. The research design combines the benefits of an in-depth single case study with increased external validity achieved through the comparison of multiple cases [18].

The research team has worked closely with the case companies for two years, gaining thorough understanding of their operational challenges and opportunities. The company documentation describes the companies' production systems, including the official organization structure and operational principles. 10–20 employees were interviewed in each case company. Company documentation and transcribed interviews were coded for recurring themes [19] Findings were later on discussed with central management, adding respondent validation.

The case companies were chosen based on similar global market pressures for lean and quality, for having manufacturing plants in Norway, and for having different expected maturity level in terms of integrating lean and quality in their production systems.

### 2.1. Framework

A framework for analyzing the relationship between quality, lean and profitability is based on the socio-technical lean model presented by Morgan and Liker [20]. This model highlights the dependability between skilled people, technology and processes, which are represented on the left hand side in Figure 1, with a set of factors describing each of them. The model is differentiated when it comes to the definition of moderators.

**First**, we emphasize that technology are inherent both in products and manufacturing equipment, claiming that a firm can face different maturity levels and stages depending on the pathway from enabling technologies [21]. From the point of maturity level, which is regarded as a model moderator, there can be outlined different scenarios. For instance a company that has a first mover strategy may benefit from successfully developing a new product that hits the market – despite initial quality errors or delivery problems. This can be resolved by time, adding to the level of maturity and sustaining profitability by reduced costs of poor quality.

**Second**, process enablers are subdivided into standardization and stabilization which are core elements in optimizing a firms value stream [15]. Standardized work, which is described, followed-up, and improved by those who are supposed to perform the task, is a prerequisite for improved stabilization and quality. Degree of stabilization also tells when a process is ready to be improved [12], whether the step is incremental or radical. But, here as well, huge deviations can be observed in parallel with reasonably profits due to operations in high margin markets.

**Third**, people play an essential role in mastering technology and processes [7]. A simplified path from people to a learning organization can be modeled through culture and structure and the transferability of knowledge [22]. Structure can be viewed as the context of explicit knowledge which is regarded as relatively easy to codify and transfer. The culture dimension, tacit knowledge, is more personal and difficult to articulate and codify, described as know-how embedded in

daily task performance [23]. Knowledge as a moderator says something about the depth and breadth of organizational competence. Organizations can on the one hand have experts occasionally lifting the company towards excellence and on the other hand build a more robust quality system involving shop floor workers and managers.

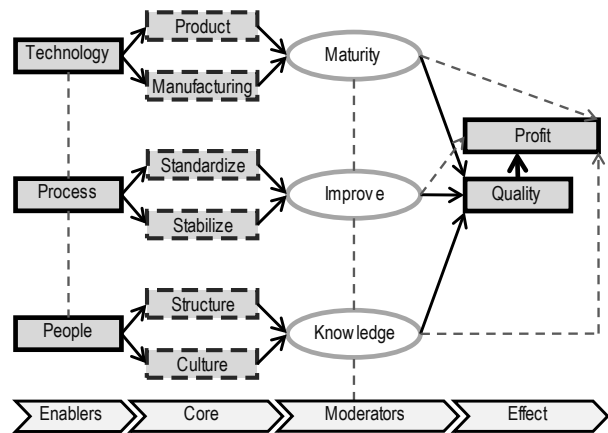


Figure 1. Research Framework

## 3. Results

### 3.1. Case A

**Case A** is a family owned company developing and producing thruster systems for the global ship building industry. It employees about 300 employees, and has for years earned decent profits. By taking systems responsibility for critical safety and navigation equipment the company has found a market niche for ships demanding frequent quay visits and high precision level, such as supply boats, ferries and cruise ships. The key to sustaining this market position is reliability and relatively low lifetime product costs.

The export ratio is increasing due to the fact that ship building has become a global industry where over 90 % of the tonnage is built in Japan, South Korea, and China. New and demanding customers put pressure on the case company to become certified in accordance to ISO 9001, ISO 14001, and OSHAS 18001 – statuses the company does not have today.

Historically, the company has managed to be ahead of their competitors with regard to product functionality and reliability, meaning that they score relatively high on introducing new product technology. This technological position is, however, gained by quite conventional manufacturing equipment and systems, meaning that the competitive advantage is their ability to develop state-of-the-art product technology, giving a steady stream of profit despite in-house quality challenges. The latter is described as a considerably amount of rework, which is detected internally before products are released to the customer. A high degree of one-of-kind production, in addition to costly materials and value added processes, means that the scrap rate is as low as zero, since the cost of scrapping normally exceeds the cost of rework.

These findings point to improvement potential when it comes to processes, specifically for standardization and stabilization. Since the company grows, it ultimately needs more space for operations, and new investments are compared against capacity potentials in existing locations. Here, the amount of rework and other wastes are detected and measured, and become objects to improve by increased focus on work processes. Blue collar workers at the case company are used to take responsibility. For instance they do not hesitate to call upon attention if there are mismatches between technical drawings and what is possible to realize in practice. This is an asset, but depends heavily on individual judgment, competence, and experience – or in other words tacit knowledge. Expanding capacity by adding working shifts and foreign workers will further challenge this marginal and individually dependent practice – increasing the demand for translating the tacit to knowledge into explicit knowledge.

Summing up the results, by the moderators, the company earns their profit by high level product technology developed and manufactured by local experts, giving room for improvements in work processes and reliable quality. However, they are at the moment introducing a holistic production system that includes QatS, which is seen as prerequisite for expanding business.

### 3.2. Case B

**Case B** produces primary aluminum in a magnitude of 2.4 million tons per year – from plants around the world. Pure aluminum is extracted from alumina during an electrolysis process. The material yield, product quality and energy consumption are highly dependent on three critical processes; anode operations, alumina control, and heat balance. These key processes are interlinked, and together they define production stability which is essential for improving competitiveness in the industry. Therefore, standardization of work processes, and how to organize for following-up and improving these standards, has been a focus area for years.

Aggregated numbers from 2009 to 2013 show 14 % improvement in terms of tonnage per employee and 30 % decline in customer complaints. Improvements are derived primarily from increased stabilization of conventional and existing production technology. Thereby, the moderator maturity ranks high both when it comes to product and manufacturing technology, with a few exceptions for special alloys delivered from next door cast houses. Not being a niche producer, the flip side of a high maturity score is that the company is solely dependent upon commodity prices set at the London Metal Exchange. The same high score can be associated to the moderator improvement as well. This is based on achieved cost and quality results, but foremost the underlying work of standardization of key enabling processes.

The case company's production system emphasizes standardization as one of five core principles, and the basis for improvement, in both production and quality system, are Standard Operation Procedures (SOPs). These procedures are derived from praxis, meaning that the initial set-up of a SOP is created by those who are most familiar with the real processes. Improvement proposals serve as input to a cross

functional group responsible for refining the standard. Involvement and employee driven improvements are manifested through that all employees are member of at least one improvement team - responsible for either critical processes or TPM (Total Productive Maintenance) activities.

The mandate of a critical process group is to standardize and improve key processes – based on input from several channels. Examples of channels are recorded KPIs from each shift, observations made through SOP-WOC (Standard Operation Procedure - Walk, Observe, Communicate), which are planned points in time where management, technical staff and operators in commonality check to what extent work is performed according to the standard, and general input from shift representatives, deviation database, technical supervisors, and TPM groups.

These reflections demonstrate the closely linked process and people view, where the formal competence system goes in parallel with work procedures. The continuous process of aluminum production requires presence of operators 24/7/365, so explicating knowledge through standards, routines and check lists are defined as a means to stabilize production and improve quality.

This case company has a long history of improvement programs, starting in the early 1980s with TQM initiatives with successive programs during the 1990s and 2000s. Long term history of improving operations explains some of the relatively high scores on maturity, improvement and knowledge.

### 3.3. Case C

**Case C** develops, produces and delivers different structural extrusion based products to the automotive industry. The main products are crash management systems for cars, both front and rear, which consist of a bumper beams and crash-boxes in a multitude of configurations aiming to reduce damage to exterior components in low-speed impacts and keep the front structure together in high-speed impacts.

Beyond the safety requirements, one of the main advantages is the use of light weight solutions, contributing to reduced fuel consumption and emissions during the use phase of the product. Hence, the product technology is regarded advanced in terms of functionality and weight reduction, but mostly to be found in the premium car segment due to high unit price.

The company was sold in 2009 from a partly owned Norwegian governmental firm to a multinational automotive company employing more than 20.000 employees. Today, the Norwegian plant employs about 500 people. Operations include an integrated value chain with cast-house, aluminum extrusion and forming technology. The equipment is rather conventional and well-proven manufacturing technology. Their competitive advantage is related to tooling technology. Stability, reliability and efficiency are keys to remain a mass producer in Norway. These keys are also reflected in their continuous improvement work, which has a relatively long history in the company.

Back in 1980s, customer impulses and contracts in the automotive industry stated an expected yearly price reduction

due to anticipated internal learning curves. Successively, these expectations were expressed as focal areas in terms of quality and zero-defect strategies. During the early 2000s a comprehensive improvement program, based on lean principles, was initiated. This program included typical elements such as TPM, just-in-time, reduced change over times, housekeeping, but also focused on team work and giving responsibility to those who were close to value creating activities. Another feature was that this lean-program was anchored, and integrated, in the existing quality and HES system. Putting quality in center and aligning it to the continuous work of reducing variation and improving tooling technology, lead to a doubling of factory up-time, tripling the number of good parts pr time unit and reducing change over time by 60 %. The scale and scope of quality improvement made the company win Toyota's quality price twice.

After the acquisition in 2009, continuous improvement is still the way of working – aiming for 5-7 % efficiency improvement annually. Quality is one of four corner stones in the new regime of the multinational owner. The main difference compared to earlier practices is that quality and lean are separated by organizational boundaries, but by overlapping goals in terms of improvement requirements. From the perspective of the research model, quality is still highlighted and improved, but with possibilities for increased cost of administration and communication. In sum, the case company has mature manufacturing technology producing high-end niche products. Despite this position, the industry gives relatively low profit margins, leaving continuous improvement mandatory. However, being part of a multinational production system may place quality in a more distant position compared to some years ago.

### 3.4. Summary of results

With the initial research framework as a basis, Table 1 describes some essential properties of the case companies.

Our results show that only one of the investigated companies (Case B) had managed to integrate quality and lean in their production systems. This company is characterized by high maturity with respect to manufacturing technology and processes. The superior integration is also due to the fact that Company B had reached a high level of maturity with respect to their production system, which also systematically incorporates QatS. In comparison, Company A had focused less on developing a holistic production system and the production system of Company C had been subject to recent revisions because of changes in ownership. Simply put, Company B has over time put in a more systematic effort to refine and sustain their production system. Company A and C have different maturity level when it comes to technology and process. However, both have developed separate organizational systems for handling quality and lean. A drawback with establishing parallel systems is increased bureaucracy and potentially poor coordination. This may lead to increased indirect costs.

Concerning the people dimension, Company A shows the most interesting pattern. Although they have a mature culture for employee involvement and problem solving, they seem to

lack a coherent structure for channeling this involvement into making the processes more mature. The other companies have less cultural maturity, but compensate by having institutionalized more mature structures for continuous improvement. These findings support the structural focus of both lean and ISO blueprints for improvement.

Table 1. Summary of Results

	Company A	Company B	Company C
Technology – Product: Maturity Level	High	Low	Medium
Technology – Manufacturing: Maturity Level	Medium	High	High
Process – Standardization: Maturity Level	Low	High	High
Process – Stabilization: Maturity Level	Low	High	High
People – Structure: Maturity Level	Low	Medium	Medium
People – Culture: Maturity Level	High	Medium	Medium
ISO 9001 Certified	No	Yes	Yes
ISO 14001 Certified	No	Yes	Yes
OSHAS 18001 Certified	No	No	No
Overall Integration Quality and Lean	Low	High	Low

### 4. Discussion and conclusion

This article sheds new light on industrial practice related to the integration of quality and lean in production systems. By drawing on operational experiences from three Norwegian manufacturing companies in global competition, new insights are revealed on how companies manage their company specific production systems strongly influenced by TPS, and customer requirements for ISO certification.

Although three case studies do not allow for broad generalizations, the results indicate that a good integration of lean and quality requires two necessary conditions. First, a high level of process maturity is important. QatS is dependent on stable and standardized work processes, designed and refined to prevent errors and deviances. This point resonates with both the “TPS-way” and the “ISO-way”. Second, the production systems themselves also need time to mature. What may start out as disperse initiatives for batch reduction, housekeeping, quality, TPM etc. may gradually be brought together under a common concept, as happened in Company B. The other companies have not yet reached this level of production system maturity. Of course this integration does not arise spontaneously, but needs to be managed and supported by experts on organizational design. Tacit



knowledge needs to be codified into ways of working that is mutually agreed on.

Findings from these explorative industrial case studies might be the starting point for further research. Questions to be picked up are the following: What is the key to successfully integrating quality and lean in production systems? How can companies who score low on quality and lean maturity levels close this gap to become integrated, without developing separate systems for the "TPS-way" and the "ISO-way"? Finally, how can companies who already have two separated organizations and systems for quality and lean merge these into one holistic and efficient production system? The answers to these questions should be interesting both to industrial practitioner and to researchers seeking new insights on production systems.

This paper has applied a qualitative and explorative methodology, well suited to research a novel topic. As the field of holistic production systems matures, research will benefit from more rigorous research models and the application of quantitative methodology. We propose the research framework of figure 1 as a starting point for developing reliable measurements that can be used to predict empirical patterns of association and causal effects.

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