



A NEW LOOK AT SOME ASPECTS OF MAINTENANCE AND IMPROVEMENT OF PRODUCTION PROCESSES

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ABSTRACT

The purpose of the paper is to present the author's reflections on the origin and popularity of various approaches to maintenance and improvement of production processes, their terminological consistency, understanding, and practical application of their principles. The author's reflections are based on his observations made over his many years of activity as a lecturer and consultant in the area of production engineering and management. It was shown that there is a need to make scientists and practitioners aware of the relatively large degree of freedom in defining the scope and way of application of strategies of continuous improvement. The author's proposal is to refer to all approaches to maintenance and improvement of production processes with the title "Strategies of Efficient Action" and all supporting methods as "Practices of Efficient Action".

Considerations presented in the paper can be useful in more and more efficiently applying the power of TQM, Six Sigma, Lean Manufacturing and other strategies of processes maintenance and improvement in the daily activities of companies.

KEYWORDS

production process, strategy, method, tool, quality, maintenance, improvement.

Introduction

In order to design goods that meet customer requirements, to efficiently produce them, a designer, product or process engineer, salesman and the like must master their jobs. In other words, they must master professional know-how. However, know-how is not enough. Today, companies must deliver something more than a basic product. They must understand the hidden expectations and needs of their customers, offer them products at competitive prices and delivery conditions, respect and meet employee needs and limit the negative effect their operations may have on the environment. To this end, enterprises should always look for opportunities for improvement production processes and efficiency.

No company can meet all of these goals if employees, technical staff and managers in particular, do not

have, besides basic professional competences, additional intangible assets that help them to be creative, discover new improvement opportunities, and understand their roles in the company by realising that every action they take has an influence on process efficiency and product quality. To recognize these challenges and face them successfully, strong motivation and a special "driving force" are needed. They can be delivered by ideas supporting innovative approach to work organization and maintaining and continually improvement of processes ability to meet customer requirements.

Such ideas have been known in industry since the beginning of the 20th Century. These ideas are known as, for example, Zero Defects [1], Total Quality Control [2], Total Quality Management – TQM [3, 4], Lean Management or Lean Manufacturing [5], Just in Time [6], Kaizen [7], Theory of Constraints

[8, 9], Six Sigma [10], Quick Response Manufacturing [11], Time-Based Management [12], World Class Manufacturing [13] or Standardized Quality Management Systems (SQMS).

Over time, a number of above mentioned and others, not listed ideas have lost their importance or have been completely forgotten, while others have thrived and gained followers. Taking into account number of relating publications, winners in this competition are TQM, Lean Manufacturing, Six Sigma, Kaizen, Theory of Constraints and SQMS. They create in a company a highly friendly environment for harmonic and synergic development of professional knowledge and additional practical skills [14, 15] of managers and employees.

TQM, Lean Management and Six Sigma are often presented in books, papers, on the Internet, and mainly in promotional materials of consulting companies as universal means to stabilize or increase company operational performances [16–20]. It is tempting to think that everything have already been said and explained in their case, and for someone who wants to introduce them in practice, it is enough to choose one of them and to start using available templates. However, this is not as simple as it seems. Organizations operate in various cultural environments, each has its own organizational and technological character, and their managers vary in approach, motivation and professional background. As a result, the variety of available and chosen solutions is enormous. This variety is on one hand positive because it provides managers many opportunities. On the other hand, it causes a kind of confusion in terminology and scope of possible application. Over the years, the same terms began to contain different contents and similar contents were named with different terms. This kind of a fuzzy perception of the ideas described in this paper is an significant obstacle in communication and exchanging experiences between researchers and practitioners.

Terminology and scope

Lean Manufacturing, Six Sigma and other ideas concerning maintenance and improvement of processes considered in this paper are variously conceptualized in the literature (Fig. 1) in terms of their perceiving and categorisation.

Relatively arbitrary, they are referred to as an idea, philosophy, conception, approach, strategy or programme [21]. Each of these terms can be justified but only on the condition that the context is explained. One can say, that:

- all are a kind of idea or philosophy because they deliver a new way of interpreting and explaining relations responsible for efficiency of processes and their continuous increase and present reasons and goals that justify their application in a company,
- they can be regarded as a conception or approach because they provide general rules and guidelines for their application (a company can choose what is most useful for it),
- they can be regarded as strategies or programmes because their goal is to gain higher efficiency in everyday operation and to gain an edge over competitors.

<i>Perception</i>	<i>Categorisation</i>
A generalized way of continuous process improvement perception.	Philosophy, idea conception
A way to achieve competitive advantage.	Strategy, programme
A set of executive measures to meet strategic and operational goals.	Methods, tools

Fig. 1. Perception and categorisation of ideas used in processes maintenance and improvement.

In some instances, if they are associated with concrete, shop-floor operational activities, they are sometimes referred to as a tool or method. However, this kind of categorisation seems to be highly inappropriate and should be avoided because it reduces the idea of Six Sigma, for example, to a simple measure, which it is not.

In the author's opinion, of all the terminology in use, "strategy" is the most appropriate. It is both wide and specific enough and leaves room for individual solutions and all activities focused on achieving the fundamental and strategic goals of a company. That's why in the following chapters, the term strategy will be preferred.

Except that strategies considered here are called so differently, the object and the scope of their action and influence is perceived variously as well. In all strategies, maintenance and improvement of resources, processes and products is stressed the strongest. Because of this terms such as strategy of continuous improvement, production maintenance or productive maintenance, excellent operations and others are practically justified. However, they are also dedicated to planning, organising, controlling, accounting and others activities. In other words, their support can be used in all areas widely associated

with management. Accordingly TQM, as well as Six Sigma, Lean Manufacturing etc., should be perceived often as one of many management strategies [21].

Strategy of Efficient Action (SEA)

A new terminological possibility, proposed here by the author and used in this paper, is Strategy of Efficient Action (SEA). “Efficient action” is a term that was introduced to literature, especially on philosophical and economic thought by Tadeusz Kotarbinski in the 1960s. Kotarbinski was a Polish philosopher who continued research on praxeology, which was defined in the 19th century by Ludwig von Mises [22]. Kotarbiński developed this term in his work “Praxiology. An Introduction to the Science of Efficient Action” [23]. In this work he defines efficient action as ability to do things in the right way. In other words, this is a positively assessed feature of action characterized by one or more practical values, such as effectiveness, economy, rationality, simplicity, etc. (Fig. 2). It can be assumed that efficient action makes the process in which they are performed efficient as well.

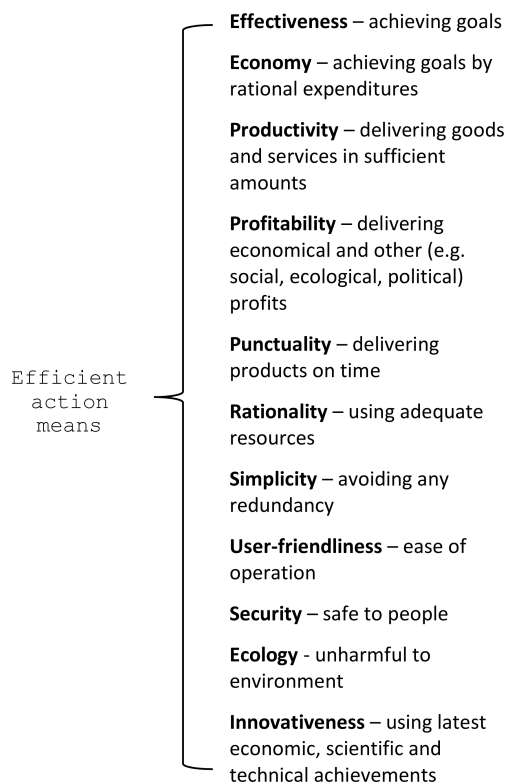


Fig. 2. Characteristics forming efficient action.

But SEAs only indicate general assumptions and goals on the path to higher efficiency. They do not have something that could be referred to as “executive power”. SEA can gain momentum only when

combined with supporting their operating principles, tools and methods and methodologies [24–27].

Practice of Efficient Action (PEA)

If a principle, a method, a tool or a set of them is regularly used in a company according to an accepted methodology, and is a part of daily routine for employees and management, it becomes a practice, defined as an activity performed repeatedly and regularly in order to achieve a certain result. It becomes Practice of Efficient Action (PEA) if its application contributes to an increase of operational and business efficiency and to a better use of employee expertise.

Principles, Methodology, methods, tools

The abundance and variety of PEA is impressive. In papers, books and on the Internet, hundreds of more- or less-advanced tools and methods are presented [21]. Having such a huge instrumentation is not simple, or even possible, to differentiate, for example, tools from methods, or even from strategies. As a result of this difficulty in practice in companies, in consulting circles, and even among people conducting research in SEA, a kind of chaos in classifying them is observed. As it was already mentioned in introduction, similar remarks refer to SEA. Strategies have a multitude of interpreters, making their perception ambiguous. For example, some people regard Kaizen as part of Lean, while others regard it as an autonomous strategy for continuous improvement. Many people view TQM as a management system; for others, it is no more than a set of principles to follow.

It can be said that there is nothing wrong with confusion of terminology. It is not Lean Manufacturing or Six Sigma that are used on a daily basis as operational strategies, but PEAs such as Kanban, 5S principles, control cards, Pareto analysis or SMED. In other words, in everyday practice, this arbitrariness in terminology has no meaning. However, in sharing experiences in practice or in scientific research, defining a generally accepted criteria of categorising tools, methods, principle or methodologies, is important. A lack of agreement on terminology creates difficulty in intercommunication between practitioners, researches, consultants, managers and other groups interested in application and development of SEA and PEA. Therefore, it is recommend to educate people on how important it is to differentiate between tools, methods, principles and methodologies.

It seems justified to accept the following definitions of principles, methodology, methods and tools:

Principles explain the strategy's directions for everyday actions, as in the following statements [28–31]:

- focus on customer needs and requirements,
- supplier partnership,
- engagement of all employees,
- turning problems into opportunities for improvement,
- preventing instead of correcting.

Methodology sets standards on how to act to achieve efficient processes. A methodology is usually presented as a **cycle of organized action**, such as:

- PDCA (plan, do, check, act),
- DMAIC (define, measure, analyse, improve, control).

Methods, such as FMEA, QFD, various kinds of DoE, MSA, and SMED, set procedures leading to achieving specific goals or effects. In order to make a method effective, it is usually necessary to combine its application with a specific methodology and appropriate tools.

Tools, similarly to methods, must be used in accordance with certain procedures; however, the procedures are quite simple and based on common sense. The main goal of most tools, such as a Pareto chart, Ishikawa diagram or Kanban cards, is to gather information regarding processes, problems, resources, etc. Tools are more universal and flexible than methods. Tools can be used in all fields of company activities and at all stages of a product's life cycle. In contrast, methods are usually oriented on specific activities and product life cycle stages.

Business and scientific roots of SEA and PEA

SEA have developed gradually and sometimes spontaneously throughout the past 100 years [32, 33]. Their origin can be dated back to the beginning of the 20th century, when Ford Motor Company started employing quality control inspectors. Soon a statistical process control was invented [34]. In the 1950s and 1960s, control activities were supplemented by a systematic approach to quality assurance, such as auditing areas responsible for quality and, above all, management taking over responsibility for quality assurance. These actions were meant to lead to a zero defects situation. At the same time in Japan, the first ideas on what today is known as Lean Manufacturing were being born.

It is difficult to set a specific date where a specific SEA started. Only in the case of Six Sigma, Theory of Constraints and Standardized Quality Management Systems can a reasonably accurate period

of creation be determined. ISO 9001, the first Standardized Quality Management Systems was created in 1987 when relevant standard was published. Designing and improvement processes according to principles described in Six Sigma conception originated in 1986 in Motorola, the telecommunication company. Theory of Constraints has its origin in the book titled *The Goal*, written by E.M. Goldratt and published in 1984.

As for Lean, Kaizen and TQM, it is less clear how it all started. Thinking in categories such as *Kaizen* and *Lean* stretch back to the fifties or even forties of the last century and is strictly linked to the Japanese industry searching for their own development path which would be adapted to their cultural and economic character. The main part in this was played by Toyota and their TPS (Toyota Production System) [35]. The term “kaizen” first appeared in 1986 in a book by M. Imai titled *Kaizen. The Key to Japan's Competitive Success*, and is referred to as a systemic approach to improvement. The term “lean manufacturing”, on the other hand, was popularised in the book *Lean Thinking: Banish waste and create wealth in your corporation* [5]. It is even harder to establish the beginning of TQM, as it is not easy to find a publication where it was first used. It is certain that their most renown promoters were J.M. Juran, W.E. Deming and P.B. Crosby, J.S. Oakland, J. Dahlagard and that the term generally started to appear in literature at the end of the 1980s.

But the foundation of TQM was laid by many others as well, even in former Communist countries, with their centrally planned economy. A good example of this is T. Olejnik [36], who wrote in 1954 that to be efficient and meet customer demands an enterprise should:

- run consistently daily analysis of complaints and quality defects and found out the causes and setting up appropriate countermeasures for the future,
- run quality scorecards on honorary boards along with names of top workers, announcement of top quality performers via paper and public radio,
- track economic indicators impacting the company's condition,
- organize competition to achieve best quality,
- build up champions' sense of responsibility for the level of quality,
- organize trainings based on the analysis of quality defects and deficiencies.

Olejnik also postulated a continuous strive for rationalization by:

- providing adequate effort to maintain the machine tools,

- preventing down times of machine tolls by increasing responsibility of the repair crew,
- increasing the level of production culture by: eliminating lack of effort, fully taking advantage of the available work time and machine work load, proper organization of a workplace, mainly, maintenance of cleanliness and order of the workplace, exemplary cooperation between peers.

It is easy to notice that some of these advices are strongly convergent with TQM basic rules which were announced among other by Deming in the seventies and Lean Manufacturing, which were published in shortly later.

It is also remarkable that the main strategies contemporary companies rely on (Lean, Six Sigma, Kaizen, ISO 9000) were created in a very short time frame – in the eighties of the last century. Strategies that were popularised after them, such as e.g, Quick Response Production or World Class Manufacturing, are only a kind of their transformation [37]. They do not offer any new or original PEA. They are limited to setting specific goals which are realized by generally available set of tools and methods.

It was mentioned in the previous chapter that there is a sort of terminological “mess” in distinguishing different SEA and PEA. It seems that one of sources causing confusion concerning the terminology is the mechanisms of creating new SEAs. A hypothesis can be formulated, that their development is a result if impulses coming from two sources: ideological and business and scientific.

Business source refers mostly to strategies, only partially to principles. That source is the need of success in business, the need to gain an edge over competition, and frequently, the need to be original. That source is not backed up science, but it does manifest elements of sociology, psychology and marketing or rivalry. Scientific source derives from human’s nature of pursuing the need to objectively describe, explain and create or control the surrounding world, including cases and relations in production and business processes [10, 38]. Such features have various statistical tools, such as Pareto or FMEA, MSA, production levelling, push principle and many others that belong to PEA. They either describe or help to describe things exactly as they are. With their use is also possible to affect the process so that they become more effective and sufficient. They can be used purposely, effectively and autonomously everywhere regardless of the environment (i.e. external and internal conditions).

Not all new SEA get beyond a philosophy or conception status and reach a necessary level of maturity to become a working strategy. A mature conception:

- has been made public,
- has clear goals specified in an attractive way and is goal-friendly,
- refers to universally recognized values,
- offers a set of operational tools and methods giving it its driving force.

Out of all the conceptions, even the mature ones, only a handful become winners, meaning those that become applied SEAs. The winners are conceptions that appeal with their attractiveness and effectiveness. They often become object of worship or faith. To become such, a conception should:

- bring spectacular results in a company that is classified as a business leader (for Lean Manufacturing it was Toyota, for Six Sigma – Motorola),
- find their own advocates that are able to promote them in books and other publications (for TQM it was Deming, Kaizen – Imai, TOC –Goldratt), and also on the Internet today,
- have followers that eventually become their advocates (Standardized Quality Management Systems have their advocates in millions of companies all over the world).

The winning SEA eventually stops being unique. Therefore, it is used by many companies and in itself does not guarantee competitive predominance. The way it is interpreted becomes the field of competition, in particular, how a given company can use the SEA’s advantages to achieve its goals. Leadership, core values and company’s culture are the key parts that lead to a company’s success.

Uniqueness and complementarity

Each SEA is unique; however, they are all complementary to each other. What differentiates them from one another are their foundations and main principles. For the most renowned and practiced SEA, such as TQM, Lean Manufacturing, Kaizen, Six Sigma, Theory of Constraints and SQMS the basic principles are:

- TQM assumes the involvement of all employees in consistent fulfilment of customer demands, needs and expectations [39],
- Kaizen uses every opportunity for improvement [7],
- Lean Manufacturing focuses on eliminating all waste and strives for the fastest possible value flow [40],
- Six Sigma decreases process variation through understanding its root cause and creating conditions increasing product and process resistance to its influence [41, 42],

- Theory of Constraints identifies and controls bottleneck processes while simultaneously recognizing that their location dynamically changes [8],
- Standardized Quality Management Systems point out the need to standardize operations, especially when they occur repeatedly [43].

Results of implementing a given SEA are determined by engagement, knowledge and skills of managers and employees. But in each SEA they are needed at a different level. In some, knowledge and special skills are crucial for success [44]. It is difficult to implement, for example, Six Sigma, Lean Manufacturing or TOC without a good background in production organization, work time study, experimenting methods or statistical tools. In other SEA, expertise is not required unconditionally. For example, in Kaizen and TQM it is engagement and readiness for improvement that are the most important features. The tools used here (e.g. Ishikawa diagram, 5Why chart, control sheet and others) are often implemented intuitively and the ability to think logically, associate, gather and process information are enough to use them effectively and efficiently (Fig. 3).

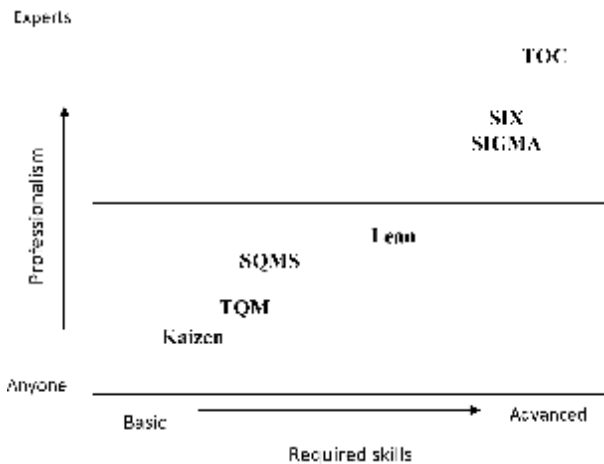


Fig. 3. Required employee professionalism and skills [45].

Operations characteristic to a given SEA either have to take into account a company functioning as a whole or be limited to one location (e.g. work station, production line). They can focus on what is visible or analyse problems deeply, and look for hidden solutions but operate from a narrow perspective. Six Sigma can be described as conception of localised operation but diving deeply into problems (Fig. 4). Lean Manufacturing and TOC must take into consideration comprehensive areas of production systems, because they operate on flow (change in one

place can cause unexpected disturbances in another place).

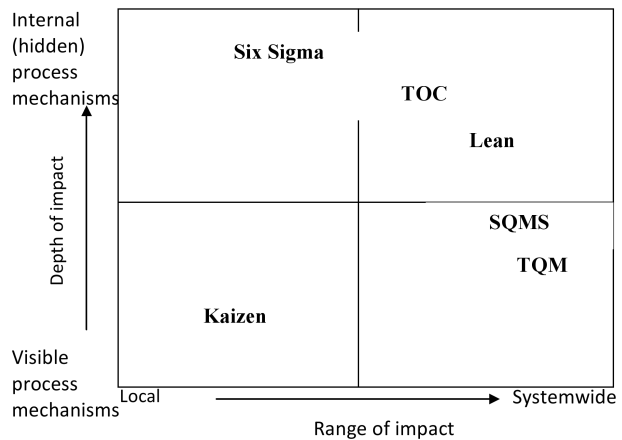


Fig. 4. Range and depth of impact [45].

SEAs differ also in requirements of creativity or analytical approach [44]. Improvements performed in form of Kaizen projects require mainly creativity and intuition to be successfully implemented. The use of statistical tools or advanced methods like FMEA is not necessary here. Six Sigma however does require strong analytical approach. Lean is also based on analytical approach, but not as advance as in Six Sigma.

A thoughtful use of each of the considered SEA results in reduced loss caused by waste and improves qualitative capacity of processes and resources. However, Lean Manufacturing and Theory of Constraints are the strongest in revealing and eliminating waste (Not Value Added operations and Business Value Added operations). Six Sigma and Kaizen, on the other hand, strengthen process capabilities in order to create added value (Added Value operations). TQM and SQMS provide these operations with motivation and formal support (Fig. 5).

The presented reflections highlight the purposefulness of treating all discussed SEAs as a set of strategies complementing and reinforcing one another [46]. Especially useful and commonly practised is combining Lean and Six Sigma strategies and creating a new one called Lean Six Sigma [18, 26, 40]. Lean ensures efficient waste reduction and, as a result, increase in process effectiveness. Six Sigma successfully minimises discrepancies, which is not possible without increasing qualitative capacity of processes. Lean Six Sigma complemented by Kaizen projects, TOC tools in the area of constraint management and supported by TQM and SQMS add up to a solution of the highest potential possible.

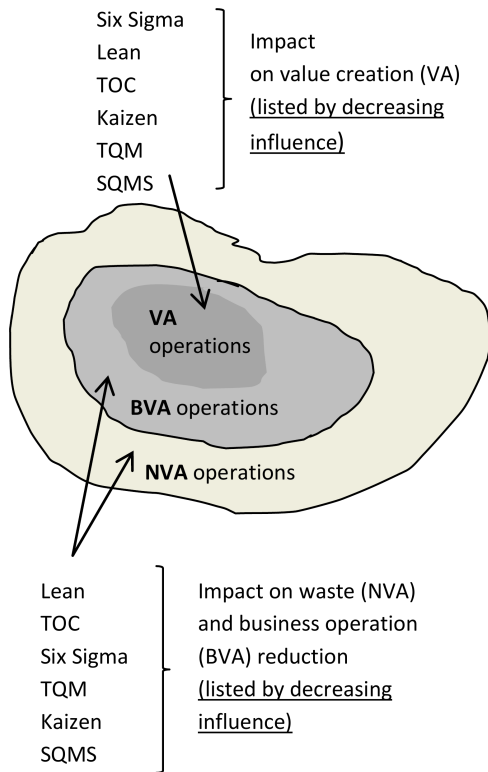


Fig. 5. Impact of SEO on value creation and waste reduction [45].

SEO and PEO as a remedy for reconciling quality, costs and time

Continual development of civilization and free market demands cause that customer requirements are higher and higher. But prices they are willing to accept should be (for products at the same level of functionality) lower and lower. Customers are ready to pay more only for new, in their opinion, more inventive products. In this context, a company must be able to meet increasing requirements without a need of increasing costs and extending customer lead time. Strategies and Practices of Efficient Actions help in reaching these seemingly contradictory goals. To this goal two ways of quality perceiving should be distinguished:

- quality designed and described in the product design and its specification. This quality is the higher the more customer needs, expectations and demands are taken by the design into account. Each product delivered to customers must fulfil this specification completely
- quality of manufacturing or servicing process. This quality gets the highest value if all the requirements specified in design are met the first time (without rework or scrap) in the scheduled lead time.

With the current level of technological and work organization development, and with available materials, nominal costs of manufacturing are higher:

- the more functions the product design includes,
- the better materials are used,
- the better accuracy and precision is demanded.

The professionalism of designers, technologists and production workers is crucial in establishing how much cost and how much time is needed to manufacture the product correctly the first time. These costs (and time) are output values that depict a kind of state of balance (Fig. 6a).

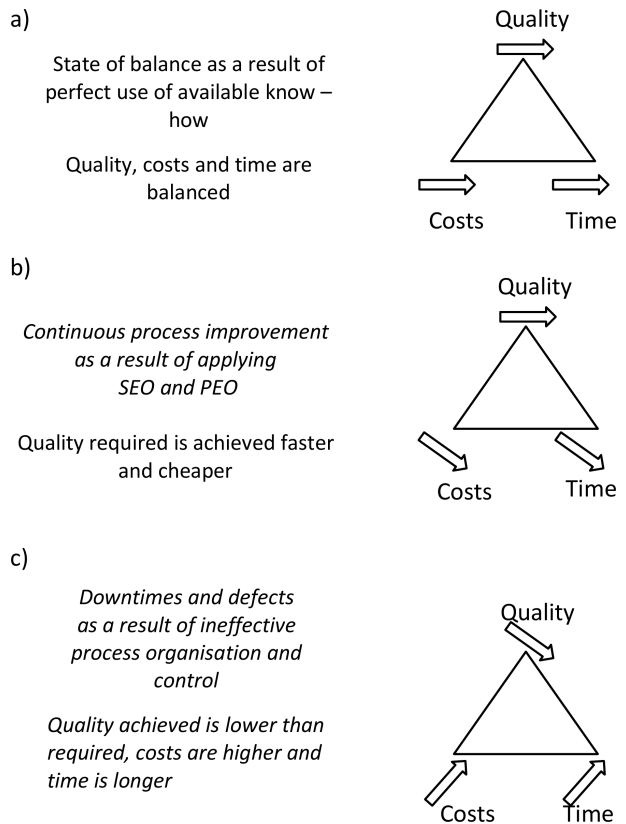


Fig. 6. Variety of relationships between quality, costs and time.

However, it is possible to gradually decrease costs and shorten lead times without negative influence on product quality. This requires increasing the speed of value flow and avoiding all situations where waste can be created first of all in the form of rework necessity or in extreme situation scrap work (Fig. 6b).

Unfortunately, in many cases the exact opposite situation can occur. Cost can grow and time can increase due to downtimes, excessive inventory, necessity to correct defects if the product is not made according to desired quality the first time, machine break-downs and so on (Fig. 6c).

Properly used SEAs and PEAs make it much more possible for situation (Fig. 6b) to occur than situation (Fig. 6c). SEA and PEA make production system more immune to changes in demand and changes in resources availability. All principles, practices, methods and tools make up a system – they all complement and strengthen each other, as illustrated in Fig. 7.

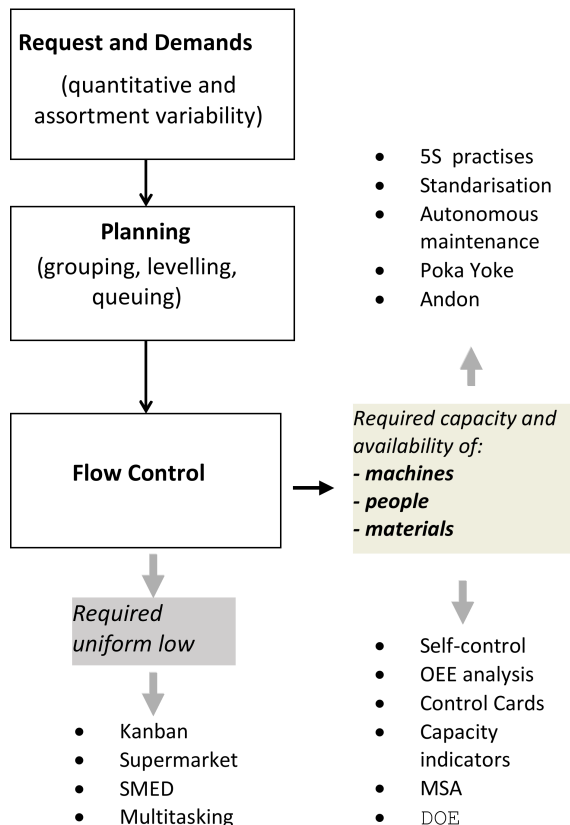


Fig. 7. Set of principles, methods and tools used in Practices of Efficient Action (PEA).

The left column in Fig. 7 shows principles and methods used for planning and scheduling production and controlling its flow which allow to limit effects of variability in demand. They are, for example, rules of grouping products, production levelling, prioritising and “pulled” production. However, these measures can be taken only when production resources are fully available: machines, equipment, materials and employees’ competences. It is not enough to have them physically available, they have to have suitable capacity to fulfil quality requirements. To help to achieve those goals, many practices, methods and tools have been designed. Out of these tools, many are often used and are highly effective: TPM (Total Production Maintenance) with autonomous maintenance, SMED (Single Minute Exchange of Die), 5S practices, work standardisation,

Poka Yoke, SPC (Statistical Process Control) with control cards and quality capacity indexes, results and performance visualisation. For example, systematically showing OEE (Overall Equipment Effectiveness) index, which measures machine utilisation effectiveness).

In reality, the simplest solutions are the most effective: 5S practices, autonomous maintenance, SMED and work standardisation. 5S practices and autonomous maintenance help employees to keep their work station in proper condition and thanks to that to focus better on their main tasks. Research shows that implementing only these two tools can increase process capacity considerably. Implemented instructions from SMED method allow to shorten preparation (i.e. changeover) time of a work station (e.g. machine line, production line) for realisation of new tasks. It is especially important to distinguish external operations from internal operations in the changeover process and realisation of the former while the machine is still involved with the previous task.

Summary

Strategies of process maintenance and continuous improvement commonly known as, for example, TWM, Lean Manufacturing, Six Sigma, have been for the last several decades a strong tool for making companies more efficient and competitive. At the same time they are a controversial subject of discussion among researchers and practitioners. Both groups brought and are still bringing new ideas and solutions to this strategies based on their own interpretations and supplements. This makes it more and more difficult to recognize the original ideas from their ongoing forms. On one hand, it is not that bad. The most important is that a strategy works efficiently in concrete companies. On the other hand, such a blurring of the original ideas makes exchanging experiences more difficult and inhibits their development, for example by enhancing them with new rules and tools.

The author’s intention is to familiarize readers to the relatively wide range of freedom in defining the scope and way of application of strategies of maintenance and continuous development of production processes. The author’s proposal is to refer to these strategies as “Strategies of Efficient Action” and to refer to methods and tools as “Practices of Efficient Action”.

The paper should be a small contribution to remembering origins of these ideas, showing relations between them and ordering the terminology used

for their description. This knowledge can be helpful in using the power of TQM, Six Sigma, Lean Manufacturing and others strategies of processes improvement more efficiently in companies every day activity.

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