International
Journal
of Advanced Research in Engineering& Management (IJAREM)
ISSN: 2456-2033 || PP. 12-28

Applicability of Total Quality Management Principles in the Context of Industry 4.0

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Abstract: Industry 4.0 will certainly affect management and management principles. One is the Total Quality Management which has been the most valid management model in the world for improving organisational efficiency. This article discusses the status of Total Quality Management (TQM) principles in a smart factory and in an Industry 4.0 environment and provides systematic definition to guide managers who have been challenged with dramatic changes with Industry 4.0. A theoretical application position of TQM principles is identified and illustrated which shows TQM principles within vertical and horizontal layers of Industry 4.0 where it is seen that some of the principles become "natural components" rather than "principles".
Keywords: Industry 4.0, smart factory, TQM, TQM principles

1. Introduction

Industry 4.0 was presented first at the "Hannover Messe" in 2011. Since then, Industry 4.0 has been already pushing more and more changes not only in technology but also in our daily lives as end users of products and services. There is no doubt that these changes will encourage new improvements in management methodologies in business.

TQM as still one of the widest applied management model in the world has been practiced to get continuous improvements in organizational performance (Gharakhaniet al.,2013). Industry 4.0 applications has the same aim in business sectors with higher efficiency and quality improvements not only on outputs but also in processes.

With this perspective, TQMprinciples can be expected to be challenged with Industry 4.0 or even to be replaced with new ones. This should be discussed from now because innovations in product manufacturing or inservices will boost new and convenient methodologies in Industry 4.0.

In this article, TQM principles and their applications were discussed and evaluated with connection of Industry 4.0 in manufacturing with special attention to Smart Factory concept. The hypothesis is Industry 4.0 has impacts on both technical and organic components of TQM either positive or negative way. The beginning challenges of Industry 4.0 in terms of management are about leaders' roles, employee commitment, team works in manufacturing which corresponds to the most influential dimensions of TQM as mentioned in the article of Hung*et al.*(2011) and the primary focus of quality management of ISO(ISO, 2015).

The article is composed of five parts subjects to the points mentioned above; introduction, literature research, theory and hypothesis of Industry 4.0 and TQM; an evolutionary study and Results

The rest of this article is organized as follows;in literature research section, the main features of TQM and the components of Industry 4.0 are introduced. The Industry 4.0 and TQM principles' interaction is clarified and re-evaluated thus their new forms are outlined from the perspective of "Industry 4.0 and smart factory" framework in the theory and hypothesis section. Finally, a graphical illustration and prototype graphical design of new status of TQM principles within Industry 4.0 are presented with suggested possible future researches.

2. Material and Method

2.1.TQM and TQM Principles

TQM is a systematic quality and continuous improvement approach to increase performance in customer satisfaction, quality, productivity, profitability for overall organizational management (Gharanhani et al., 2013).From the management perspective, TQM has a vital role in developments of the management practices (Prajogo & Sohal, , 2003a; 2003b).

Deming (1986); Juran (1988); and Crosby (1979) who are gurus of quality management, developedfundemantel formulizations of TQM practices (Bon & Mustafa, 2013). Based on their frameworks, several studies and researches have been implemented (Saraph et al., 1989; Flynn et al., 1994; Anderson et al., 1995; Powell, 1995;Prajogo&Sohal, 2003a, 2003b; Zairi, 1997).

According to the most previous studies, that the most influential dimensions of TQM include;

(a) top management support,
(b) employee involvement,
(c) continuous improvement, and
(d) customer orientation or customer focus in other term

(Juran,1988; McAdam &Armstrong, 2001; Prajogo&Sohal, 2003a, 2003b; Zairi, 1997; Hung *et al.*, 2011).

According to International Standard Organization (ISO), the primary focus of quality management is to meet customer requirements and to strive to exceed customer expectations, and it is important to involve all people at all levels in achieving organizational quality objectives (ISO, 2015).

It is obvious that, an organization should have an ongoing focus on its improvement for being successful in the market.

The TQM principles are defined by researchers by different names or categories in the meantime. Also, many authors have derived the critical success factors of TQM such as Black and Porter (1996) using Malcolm Baldridge Award criteria, Tamimi and Gershon (1995) by developing a measurement instrument (Yusof&Aspinwall, 1999). For example, Saraph*et al.* (1989), Flynn*et al.* (1994), Powell (1995), Ahire*et al.* (1996), Black and Porter (1996), and Zeitz*et al.*(1997) have used 17 common TQM factors in their models, although different terms are used (Hoang*et al.*,2010). On the other hand, Prajogo&Sohal (2003a) investigated the relationship between TQM and organizational performance and divided the TQM factors into 2 groups as “mechanical components (technical elements)” and “organic components”. This distinction is based on the argument of Kruger (1998, 2001).

In a study by Rahman and Bullock (2005) with 261 Australian manufacturing operations, 10 TQM principles were deducted by use of Dow *et al.* (1999) and Power*et al.*(2001) defined factors. 6 of them is categorized in organic / human elements and 4 are considered as technical components of TQM (Hoang *et al.*,2010).

The TQM principles definitions by different researchers/ resources are summarized in Table 1.

2.2. Industry 4.0

There were four major industrial revolutions that fundamentally changed the production processes in the recorded history since the end of 18th century. The first began with the discovery of mechanics that enabled more efficient use of water and steam power.

The 2nd industrial revolution began in the early 20th century with Henry Ford's production band design. This development has also enabled the start of the use of electricity in mass production and the development of the production line.The 3rd industrial revolution began in the 1970s with the use of programmable machines, which caused mechanical and electronic technologies to leave their place in digital technology.

Nowadays, there is a great development that has not yet been defined as an industrial revolution but has the qualities of being an industrial revolution; Industry 4.0.

There is a general shift in productivity and productivity in the industrial sector by leveraging ICT information and communication technology around the world. The name given to this trend's German approach is Industry 4.0. Industry 4.0 aims to "maximize the communication among people, machines and resources at the highest possible level", leaving centralized production control processes to autonomous and processes managed in place (Baenaa*et al.*, 2017).

Industry 4.0 does not have an official definition yet. There are many definitions. Some of them are (Mrugalska&Wyrwicka, 2017);

"The integration of complex physical machines and devices with sensors and software within the network structure to provide predictions, control and planning for better business results and social outcomes"

"A new level of value chain organization and management throughout product lifecycle",

"A collective term for concepts of technology and value chain organization"

The maximum level of the mentioned integration and technology used within Industry 4.0 is not foreseen yet. Most probably the revolution will go on until minimum human contribution in processes and this will describe the ultimate integration level.

According to Lin et al. (2018), “Industry 4.0 refers to the idea of industrial revolution that allows the manufacturing to be customized by integrating production processes and the information technologies and techniques.”

Still, existing academic literature is insufficient for a clear and agreed definition of the Industry 4.0. That’s why, Industry 4.0 has fuzzy image among researchers and especially among practitioners (Hofmann & Rüsch, 2017).

Table 1TQM Principles in different formulations

by Saraph*et al* (1989), Flynn et al. (1994), Powell (1995), Ahire*et al*., (1996), Black& Porter (1996),and Zeitz*et al*. (1997) (compiled by Hoang *et al*., 2010)	by Prajogo and Sohal (2003a)	by Rahman and Bullock (2005)'s study in 261 Australian manufacturing organizations, Dow et al. (1999) and Power*et al*.,(2001) (compiled by Hoang *et al*., 2010)	by ISO 9001:2015 Quality management principles (ISO, 2015)	By Erkılıç, 2007
1. Role of top management 2. Customer satisfaction 3. Teamwork structures 4. Authorization of employees 5. Involvement of all employees 6. Employee training 7. Product / service design 8. Supplier management 9. Continuous improvement 10. Process management 11. Quality improvement measurement systems 12. Quality data and reporting 13. Planning 14. Benchmark 15. SPC-statistical process control 16. Company quality culture 17. Strategic quality management	Mechanical components; 1. Customer orientation 2. Process management 3. Strategy and planning 4. Knowledge and analysis Organic components; 5. Leadership 6. Management of people	Organic (soft) principles: 1. Employee commitment 2. Share of vision 3. Customer orientation 4. Team working 5. Employee training 6. Cooperative supplier relations Technical principles: 7. Computer based technologies 8. Just In Time 9. Use of Technology 10. Continuous improvement providers	1. Customer focus 2. Leadership 3. Engagement of people 4. Process approach 5. Improvement 6. Evidence-based decision making 7. Relationship management	1. Results orientation and customer focus 2. Functional leadership 3. Management with process and data 4. Continuous functional training and human resources management 5. Cooperation and corporate social responsibility

2.3. Key components of industry 4.0

There are four main components of Industry 4.0 came up so far; CPS, IoT, IoS and Smart Factory.

CPS- Cyber physical systems; a characterised component of Industry 4.0; providing with a connection via the internet or other distributed ledgers i.e. integrations of computation with physical processes. This means, high synchronisation between physical shop floor and the virtual computational space which will make manufacturing processes efficient, transparent, and totally controlled (Hofmann&Rüsch, 2017).CPS-cyber-physical systems monitor physical processes, create a virtual copy of the monitored physical environment, give local decisions in other terms decentralized decisions. CPS communicate and interact with each other and humans in real time via IoT.

IoT-Internet of Things; IoT offers a wireless data management by collecting and organizing them.Thus, IoT transformsdata to knowledge which used to activate CPS (Alçın, 2016).IoT Technologies are composed of Radio Frequency Identification, Internet Protocol (IP), Electronic Product Code (EPC), Barcode, Wireless Fidelity (Wi-Fi), ZigBee, Bluetooth, Near Field Communication (NFC), Actuators, Wireless Sensor Networks (WSN), Artificial Intelligence (AI) as summarized by Madakam*et al* (2015). All activate in five layers as sensing layer, access layer, network layer, middleware layer and application layer recommended by International Telecommunication Union (ITU) (Madakam*et al.,* 2015).

IoS-Internet of Services; having a key role in the future industries by making any kind of "services" easily available through web technologies, allowing companies and private users to combine, create and offer new kind of value-added services with internet-based market places (Hofmann&Rüsch, 2017). Customer services through horizontal and vertical chains are provided and utilized via the IoS.

Smart Factories; CPS-IoT-IoS are all interrelated in a smart factory.It is not only a connection of all manufacturing resources (sensors, actuators, machines, robots, conveyors, etc.) and automatic information exchange, but also will become conscious and intelligent enough to predict and maintain the machines; to control the production process, and to manage the factory system (Qina*et al.,* 2016).

Also, other manufacturing processes, such as product design, production planning, production engineering and other services, will be simulated easily, and as modular, and then connected closely end-to-end commanded by a decentralized system and also controlled interdependently (Qina*et al.,* 2016).

With new evolutions via Industry 4.0, products in markets will be smarter; smarter for customers, smarter for designers, manufacturers and suppliers due to transmitting data and feedbacks in horizontal and vertical chains which will motivate for further developments and excellence. Smart products become smart with IoT and CPS applications. Tracking systems such as product tracking, data tracking will be very easy and time based. The operator working in a smart factory should have improved competencies, including monitoring, verification works and needed to be trained further.

The new operator in Industry 4.0 revolution is called "augmented operator (Mrugalska&Wyrwicka, 2017).The value chains described within Industry 4.0 subject to digitization are; horizontal value chain and vertical value chain. The digitization of the horizontal layers integrates and optimises the flow of information and goods from the customer through their own company to the supplier and back involving both internal departments such as manufacturing, logistics, planning in a company and external value chains in the scope of customer requirements.

Vertical value chain digitization is associated with consistent flow of information and data from Sales through Product development to Manufacturing and Logistics (Koch *et al.,* 2015).

2.4. SmartFactory

In the article of William Pagnon, a method for factory automation from online ordering to product shipping without any human intervention is presented and summarised a concrete way to fully automate a smart factory, in a chain of online ordering-order processing-raw material processing-product manufacturing and product delivery. All of them is expected to be realized in a real time data and in a reliable technology (Pagnon, 2017).

New generation assembly line feedings, transportation between workshopswithout human interfere make possible to produce different types of products in one assembly line in a smart factory. This means increase in productivity, less quality problems, more effective stock management.There is no need to visit all of assembly lines in a company for example in pharmacy, automotive manufacturing sectors, because online monitoring makes it unnecessary, automatic reportingcreates a common language in such an organization.

A smart factory will make necessary to create "cyber physical social systems" a kind of hybrid teams – man + machine – having superior collaboration processes (Pîrvu&Zamfirescu, 2017).

Some of the advantages of "Smart Factory" are machinery breakdown prevention, removal of human error improves product quality, increase in safety as no humans interact with the machines apart from conducting maintenance, reduction of labour cost (Pagnon, 2017).

Although there are different scenarios about the human role in an organization and manufacturing, it is for sure that technology will take over repetitive works that are controlled, clearly defined and stable in a process. It can be expected that workers have to think in an interdisciplinary way due to merging IT (Schröder, 2017).

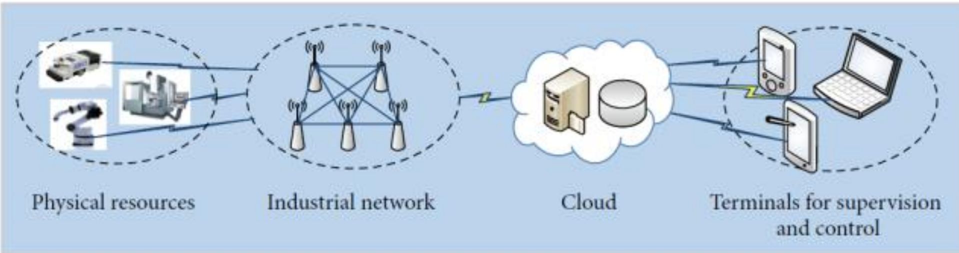

Figure 1 A framework of a smart factory of Industry 4.0 (Wang *et al.*, 2016)

Table 2 provides a comparison between a smart factory and a traditional factory (Wang *et al.*, 2016).

Table 2 Acomparison between a smart factory and a traditional factory (Wang *et al.*, 2016)

Smart factory production system	Traditional production line
Diverse Resources. more different types of resources to produce customer oriented small-lot products **Dynamic Routing.** to link resources automatically in line with manufacturing/service route. **Comprehensive Connections.** for interaction of machines, products, information systems, and people through a network **Deep Convergence.** the cloud integrates all of physical artefacts and information systems. **Self-Organization.** smart entities negotiate with any other, organize themselves and work successfully in system dynamics. **Big Data.** smart systems create a real time and massive data and the cloud can process the big data.	**Limited and Predetermined Resources.** manufacturing in a fixed line for mass production **Fixed Routing.** fixed production line only reconfigured by people with complete or partial system power down. **Shop Floor Control Network.** communication among machines is not always possible or necessary to control the network, mainly processed by humans. **Separated Layer.** devices used in a plant are separated from the upper information systems for support of management. **Independent Control.** machines perform in accordance with assigned functions. A failure in a device usually breaks the full line. **Isolated Information.** recorded process information of inside of a machine is shared/used in seldom with other data collection systems or with others.

2.5. TQM andIndustry4.0

TQMcorresponds to the second industrial revolution. Now, Industry 4.0 focuses on the optimization of the value chain as it provides autonomous control and dynamic production, increases competitiveness even further in the future.

Through the comprehensive and close networking of machines, resources and products inside the factory of the future including the entire value chain, Industry 4.0 is characterized by a huge volume of aggregated data (Mayer&Pantförder, 2014).The quality management domain these new emerging potentials of huge data such as, the new generation of performance indicators for monitoring and tracking the manufacturing processes (Aehnelt & Bader, 2014), because, methods to measure the efficiency and effectiveness of each process must be established and applied according to ISO. These methods should be applied in Industry 4.0 environtments, too (Foidl & Ferderer, 2016).It is obvious that, Industry 4.0 further provides promising opportunities for quality management for organizasations. However, both challenges and opportunities for quality management domain by Industry 4.0. In other terms, potential research challenges for the quality management domain which arise through Industry 4.0 (Foidl & Ferderer, 2016). From these point of views, there is a need both for practitioners and management science to understand new positions of TQM principles in an organization within Industry 4.0 environment to modifymanagement practices.

One example to the needs is about leadership. With Industry 4.0, leaders' competencies need to be improved more because traditional markets and product qualifications change rapidly. Leaders were leading people and now robots/virtual systems with artificial intelligence should be leaded as well.Leaders has to have ability for interaction with digital profiles. Digital leadership is a new leadership style to strength the teams in such a challenging working conditions of Industry 4.0 with increased real time connectivity of humane-machine including customers, suppliers and others (Aditi *et al.*, 2017).

Employee commitment principle should be redefined because employees will not be composed of only humans but also androids.In this case, commitment level and conditions are new challenging issues within TQM principles.

Some methodsused to apply continuous improvement principle of TQM such as Kaizen are focused on incremental improvements and the speed of evolving technology coming with Industry 4.0 may not allow to keep its importance in organizations managed with TQM.

The relationship between humans and machines will be more organic in time. CPS-based production systems will influence the human+machine interfaces, their roles and task descriptions, monitoring and controlling methods applied under SPC principles will also change. (Prinz etal., 2017;Mrugalska&Wyrwicka, 2017;Axiomtek.,2015; Hofmann &Risch, 2017). Ultimately, enterprise management will be influenced.

Strong individualization of products, high level of integration of customers and partners including suppliers, much more flexible production processes, new competency needs of human resources will give a new character to business models (Monostori, 2014; Kagermann et al., 2013, Ibara et al., 2018). To develop different ways to support the Business Models is being more important because existing researches are mainly focused on technology developments not on business models (Ibara et al., 2018).

3. Hypothesis about TQM and Industry 4.0:an evolutionary study

Industry 4.0 applied in organizations ie smart factories, brings forward many changes including management behaviours, based on researchers' statements mentioned above. Thus, it can be highly expected that TQM principles' positions in an organization and their application level shall change dramatically. Industry 4.0 may have impacts on TQM components either positive or negative way or in another direction which is researched in this section.

First, the complete range of TQM Principles mentioned in various resources is summarized and reorganized as Organic and Technical Components of TQM in Table 3. Then, re-evaluation and evolution of the TQM Principles from the "Industry 4.0 and smart factory" framework is studied in below paragraphs.

Table3. A compilation of TQM Principles

Organic Components (Soft components)	Technical Components
Communication; Relationship management Employee training Employee commitment Authorization of employees; Involvement of all employees Leadership Team work Share of vision Management involvement; role of top management Vision sharing	Quality improvement measuring systems Quality data and reporting Benchmark Customer orientation SPC-statistical process control Strategy and planning Strategic quality management Process management Continuous Improvement Computer based technologies / Use of technology Just In Time Supplier management Product / service design Management with data Information and analysis System approach in management / Planning

3.1.Technical Components

Innovations increase the likelihood of investing more in the technical components of the TQM and innovative enterprises are highly effective at fulfilling the process quality control practices (Erkılıç, 2007).

Industry 4.0 brings dramatic innovations to industries. Accordingly;

SPC-Statistical process control, Management with data, Quality data and reporting, Quality improvement measurement systems: It is envisaged that the new-period factories will implement self-inspection, control and development processes with sensors instead of human senses, using robotic production tools that take action automatically (Prinz et al., 2017). For example, as stated by Elkhodr et al. (2006),that IoT provides services based on utilizing and combining data received from various things by sensing information, collecting physiological measurements, and operational data in several segments.

Thus, with high automation, and IoT, this principle will increase its existence in a smart factory while preserving its validity for TQM.

By gathering information based on real time data, smart factory automation will become available in the network structure by activating all the data that are not actively used or collected in the past such as process control or product development or maintenance data.The management will be able to end the problems with real time data collectionand will facilitate effective data-based management of the production process and all processes.

Organizations having specific information through database and information systems, need to develop systems that will assist staff in decision making (Vujovic et al., 2012). So, automatic statistical controls and SPC tools, specific SPC methods such as FMEA in automotive sector, and others like Pareto will be applied easily and on right time based to correct failures or to take preventive actions in Industry 4.0. Thus, these principles will be a natural part of smart factories.

Due to the reasons explained above, the measurement systems developed so far will become more efficient and efficient to use in multiples in smart factories. Hence, efficiency in measurement and measurement systems become one of the specifications of Industry 4.0.

Information and analysis: This principle can be considered same with “management with data” principle.

The smart industry establishes a social network and enlarges communication channels to different stakeholders where human beings, machines and resources communicate resulting with information and knowledge sharing with each other (Sterev, 2017; Kagermann et al., 2013).

The collected huge data and information with use of CPS and IoT in smart factories will let identification of bottlenecks, unnecessarily high costs and quality issues easily and even precisely (Axiomtek, 2015).

The use of computer-based technologies / technology: In Industry 4.0, devices, machines, workshops, products are exchanging information, triggering actions and controlling each other independently via CPS and Big Data, companies implement their activities in an intelligent environments surrounded by technology (Weyer et al., 2015). Because technology is one of the fundamental revolutions of Industry 4.0, this principle is a principle that strengthens effective Total Quality implementation in Industry 4.0.

Just in Time (JIT): JIT will be highly effective and achievable principle with flexible production systems, resource allocations, vertical and horizontal digitalization as explained in a paper seeking to discuss the opportunities of Industry 4.0 in the context of logistics management, with respect to Kanban, an improved demand assessment, dynamic and more efficient milkruns as well as shortened cycle times can be expected (Hofmann&Rüsch, 2017).

Supplier management: Nowadays, Industry 4.0 continues to show itself rapidly in the logistics sector. In light of these developments, and as a result of Industry 4.0's horizontal value chain and digitization, the principle of supplier management will be preserved and will be living very effectively in a smart factory.

For example, smart factories are characterized as self-sufficient facilities on supply chain level, which source raw materials from local suppliers. Working with local suppliers decreases leading time, minimizes inventory level while increases customization and responsiveness as also described in slightly different vision by Hadar and Bilberg according to Radziwona et al. (2013).

Especialy, in a living JIT/JIS systems, reduced bullwhip effects, highly transparent and integrated supply chains as well as improvements in production planning are among the potential benefits of Industry 4.0 according to Hofmann & Rüsch (2017).

Customer orientation: Personalized product designs which are foreseen with Industry 4.0 are the result of customer orientation. Industry 4.0 allows individual, customer-specific criteria to be considered from design to manufacturing processes while enabling last-minute changes to be incorporated (Kagermann et al., 2013). By allowing to meet individual customer requirements, the smart factories become more and more customer oriented.

Product / service design: This principle is a TQM principle that manifests itself with customer orientation. By the introduction of Industry 4.0 technologies such as Big Data, virtual reality and so on, a better understanding of customer needs is possible with more improved touchpoints (Ibara et al., 2018) and products will have individualized designs (Kagermann et al., 2013). Accordingly, products and services specific to individual customers are going to increase rapidly which means very big innovations are expected in product/ service designs.

Process Management: Real-time transparency with CPS that are network in an IoT and other technologies in a manufacturing environment stop rigid planning. Hence production control and process managements become radically flexible that enable dynamic re-engineering processes (Weyer et al, 2015; Bauer et al., 2015). This means various challenges for companies, make necessary to find efficient structures and methods (Bauer et al., 2015). These challenges can be achieved through process coordination via standardised and harmonised business processes (Weyer et al., 2015, Kagermann et al., 2013).Because all elements of the system will be connected to each other and act as a network structure, the principle of Process Management will be mandatory and necessaryin a smart factory and its deceit will become stronger with new developments

Strategy and planning, Strategic quality management: Higher customer expectations, flexibility, service orientation and transforming into new business models which create higher competitive markets lead companies to be more strategic and to set up strategic alliances with their suppliers or competitors in Industry 4.0 (Hecklau et al., 2016). Both TQM principles will support the "strategic" aspect of the other technical principles that are more effectively stay alive in Industry 4.0. It will continue to be one of the most compelling Technical Principles, with increasing competition in sectors.

Benchmarking: Benchmarking measures organizational performance or processes in terms of best-in-class performers by comparisons from inside or outside of its industry.It helps in continuous improvement and better customer satisfaction by support of achieving competitive advantage (Anil &Satish, 2015). Networking, both horizontal and vertical integrations, communication and interactions as underlined by researches, smart factory applications will strengthen benchmarking principle (Bauer et al., 2015;Pagnon, 2017; Koch et al., 2015). In other terms, frequent or even continuous internal and external benchmarking will be highly possible via networked layers. In fact, the principle will be a natural output of processes.

System approach in management / Planning: Sensors by reading barcodes or RFID (radio frequency identity) tags, count parts, coming or leaving parts, smart systems can calculate the needs and initiate an order placement with the supplier by definition of time plan or production schedule. This already applied "embedded vision system" is provided by integration into a controller unit between production lines, warehouses etc(Axiomtek, 2015).

As a result, actual delivery times may be much more corresponded to planned. The existence of this principle will be facilitated easily and strengthened by Industry 4.0 developments mentioned in this article and in others will reveal the system approach concretely.

Continuous improvement: It is clear that high innovation, high efficiency in product developments, personalized services or products, management with real time data, communication and interaction of processes and networked structures will support continuous development. It is an inevitable challenge for companies in such an intensified competitiveness with these main features related to the Industry 4.0 (Bauer et al, 2015)

Because continuous improvement can be executed based on standards, the new standards are needed for Big-Data, IoT and Smart manufacturing design and analysis, robotics and so on.

On the other hand, the continuous improvement tools and techniques should be reviewed one is Kaizen. Kaizen is a process-oriented, small-step, human-based, knowledge-seeking, continuous good-looking effort (Akdağ, 2005).

In a report, it is expressed that traditional standards development efforts, primarily focused on incremental improvements of existing standards, cannot keep pace with the speed of evolving technology (Lu et al., 2016). While Kaizen is a model that allows intense participation of bluecollar employee, including operator / supervisor / technical personnel / shift workers, this can be less in their agenda with Industry 4.0.The interaction of devices, production tracking in a collaborated network with Industry 4.0 provides much more widespread optimization possibilities for the manufacturing companies. The Industry 4.0 elements such as IoT, CPS will create new possibilities for the improvement of the production and services processes for example it is much more easy to forecast equipment failures based on collected data and analysis hence machine stops and production losses will decrease (Tamas et al, 2016). Hence, Kaizen will be easier to apply.

However, in a smart factory, Kaizen may become a technique applied not only in vertical but also in horizontal value chains where external customers, suppliers are also active members of Kaizen team.

3.2. Organic components

Employee training: With increased technology and real time data, factory processes will work with higher efficiency and with increased quality. Hence, operator interventions will lessen in manual set ups, in open control loops (Axiomtek, 2015). These and much more changes have quite big potential on emerging new competency needs on employees. Unlike traditional factory workers or technicians, the Augmented Operator is required to have advanced problem-solving skills, technology use skills, complexity handling, and flexible work.In this case, employees should continue to be trained, but not in traditional methods and not in traditional scopes. It is obvious that trainings will be more integrated with technology.

Learning will be easier in the meaning of cognitive and precedural learning mechanisms which are the mechanisms proposed by Lifvergren and Bergman (Lifvergren & Bergman, 2012).

Full participation of employees / Employee commitment: Different resources express without a question mark that labour roles will shift to monitoring, safeguarding production system.

IoT can convert the data into automated instructions by eliminating many human interference roles (Elkhodr et al., 2016).For example, in a smart factory, manufacturing staff mainly will work on monitoring, specific maintenance tasks, IoT development or modifications, or will work on/with likewise information technology, etc. instead of manual manufacturing processed which are robots' or systems' jobs in a smart factory. This will pioneer analysis or administrative works rather than traditional labour activities according to Pagnon (Pagnon, 2017).

Employee commitment is expected to be easier with automation and smart factory practices because a comprehensive data-based results will direct people, motivate people, will ease operational decision makings. However, in a study of Prifti *et al*, Industry 4.0 competencies are very challenging; although the work environment will change, no concrete vision or competency models had been proposed until 2017 according to their literature analysis which should be considered in employee participation and commitment efforts (Prifti et al., 2017).

Communication and relationship management: Real time data sharing will increase communication capabilities of a factory and of the system as a whole. That means internal and external communication with suppliers, customers and internal teams will be extensive (Sterev, 2017; Kagermann et al., 2013).Time based communication with accurate information will be the natural results of Industry 4.0 with digital communications at horizontal and vertical layers(Pagnon, 2017; Axiomtek 2015).

Machine to machine, machine to human communications will be available via IoT applications as explained by Madakam et al. that the IoT is considered as a global network which allows the communication between human-to-human, human-to-things and things-to-things with a unique identity to each and every object (Madakam et al., 2015).

his brings self-controlling systems together which communicate via the Internet and human, which alters the role of workers towards coordinators and problem-solvers in case of unforeseen events (Brettel et al., 2014).

Communication and relationship management principle should be redefined within Industry 4.0 and specifically in a smart factory by considering communicated horizontal and vertical layers.

Team work: In Industry 4.0, creating a composition of cyber-physical, cyber, and human components, and IoT, Pfeiffer identified challenges that a human could be easily replaced by robots based on a qualitative survey with 62 managers of assembly plants (Pfeiffer, 2016; Kamble, 2018). Human-cyber-physical interaction works in cooperation in controlling and optimization of processes to optimize the outputs (Qianet al., 2017) in Industry 4.0. Accordingly, it is time to think about that the team definition may not be referred to as "a group of people who come together to achieve a specific goal or objective shared" anymore, but "a group of people and systems (including androids) that come together to accomplish a specific goal or goal shared".

Leadership: It is obvious that leaders are expected to improve themselves technically.Taking into account the components of the Industry 4.0, it can be concluded that there must be significant changes in both employee and leader behaviours and competencies. Forexample, more involvement, integration, knowledge management, flexibility, creativity, self-management and organization, efficiency and timeliness may be required(Hofmann &Rüsch, 2017; Kagermann et al., 2013; VDI&ASME, 2015, Kiesel & Wolpers, 2015). And teams and even employees in CPS production systems should be upgraded into better leading decision-making authorities, in the future (Bauer et al., 2015; Brettel et al., 2014).Accordingly, unlike traditional organizations, leadership will be needed at all levels and more local based. However, literature research results do not say yet that leadership will stay on the forefront of the TQM Principles or not.

Management involvement and the role of senior management: It is possible to have better industrial controls on processes, higher flexibility to meet customer needs with benefiting from virtualization, real-time capability and interoperability. Managers should work hard to overcome new challenges to sustain competitiveness which implies their critical roles in Industry 4.0 (Kamble et al., 2018). This is an accompanying principle tothe "strategic quality management" principle, too.

Vision sharing: The companies should stay competitive and the vision of Industry 4.0 takes organizations to a totally new approach to business operations including production industries ie smart factories (Erol et al., 2016, Bauer et al., 2015). So, vision sharing should continue to be one of the most important driving factor of an organization and it is clear that it will remain in the Industry 4.0 and in the TQM Principles.

4. Results

Based on above determinations, TQM principles within a smart factory can be classified in fourcategoriesas seen in Figure 2.

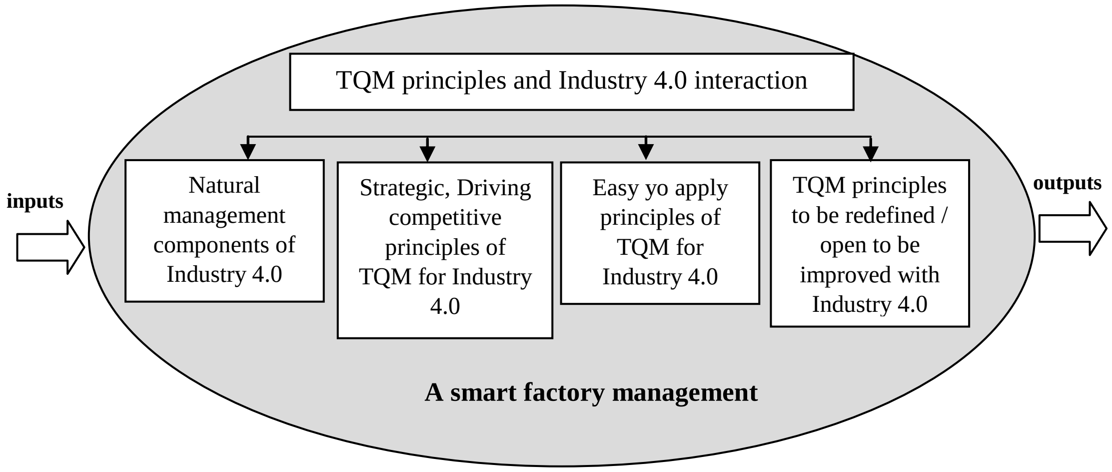

Figure 2 A smart factory management with TQM principles

Category 1; Natural (management) components of Industry 4.0

Some of The Principles of TQM can be removed and classified as "natural components of a system" because "natural existence" is an absolute component of a smart factory. For example, "evidence-based decision-making" is largely "natural components of Industry 4.0" rather than "principle".In other terms, the principles in this group are not TQM principles anymore but natural components of Industry 4.0

Category 2; Strategic, driving, competitive TQM principles for Industry 4.0

There are TQM principles which has strategic importance for an organization now and then.

Category 3; Easy to apply principles of TQM for Industry 4.0

These are the principles which become very easy to apply in a smart factory because of high level of automation, efficient data collection and analysis and other specifications of a smart factory.

Category 4; Principles to be redefined, open to be improved with Industry 4.0

These are the principles that their status and affects in management of a smart factory are already started to change and these principles need to be improved or redefined in new working conditions.

Figure 3 is a graphical illustration of above discussions and statements hence, the status of TQM principles within Industry 4.0.

The developments that come with the Industry 4.0 bring forward the humanization of the systems. The system qualifications become more parallel to the ideal human competencies which is always an expectation/aim of an organization.

Industry 4.0 and its components bring decentralization in management for decision makings and apply a living synchronization between the factory-human-machine-process-customer. In this case, it is indispensable that modern and postmodern management models - including the Total Quality Management as the most current and inclusive management model – will be affected. Therefore, in the near future, TQM as a management model should be scrutinized, updated, and strengthened to guide management and to provide a way for businesses experiencing Industry 4.0 revolutions. This is primarily expected to be achieved through further scientific academic studies.

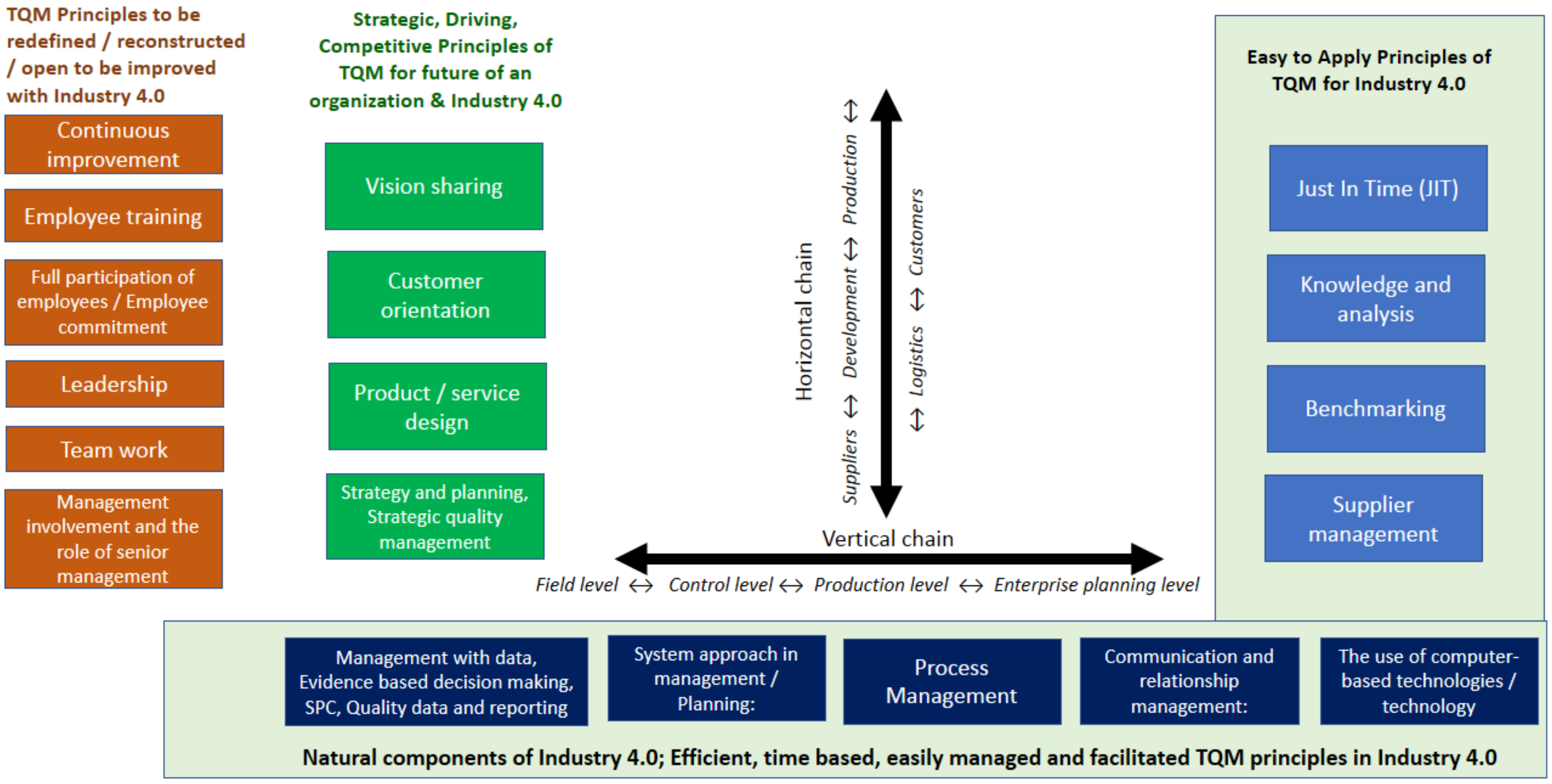

Figure3. Status of TQM principles within Industry 4.0

5. Conclusion and discussion for future

The results show us that TQM Principles should be updated because of Industry 4.0 impact. Some principles are not the management principles anymore due to their new position in a smart fatory as “natural component”. However, the principles such as customer orientation; vision sharing; product design; strategy and planning are competitive principles of an organization, and the principles such as continuous improvement, employee training, leadership and teamwork are open to be improved or redefined in the future. The easy to apply principles such as JIT, supplier management can be still an issue especially for SMEs and for organizations who are in the beginning of adopting Industry 4.0 elements.

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Industry 4.0 and its components bring decentralization in management for decision makings and apply a living synchronization between the factory-human-machine-process-customer. So, it is indispensable that modern and postmodern management models - including the Total Quality Management as the most current and inclusive management model – will be affected. Therefore, in the near future, TQM as a management model should be scrutinized, updated, and strengthened to guide management and to provide a way for businesses experiencing Industry 4.0 revolutions. This is primarily expected to be achieved through further scientific academic studies.

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