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Measurement of Results of TQM System Implementation in Complex Production-Business Systems

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A B S T R A C T

The primary objective of this paper is to conduct a measurement of the results of implementing the TQM system in the context of its integration with Industry 4.0. The paper identifies factors influencing the implementation of the TQM system. Based on the alignment of ISO 9001:2015 requirements and the characteristics and technologies of Industry 4.0, the interconnection has provided the opportunity for the production system to be more flexible, as the entire system is interconnected, and each unit of the production system knows what is happening in other units at the micro or macro level. Moreover, the real-time flow of information from machines, objects, and the workforce to and from factory management has made the decision-making process more efficient, reliable, and fast. Using the example of three business systems, measurements of implementation factors were conducted. The measurement revealed that the business systems have sufficient available resources and a sufficiently high initial level of quality for QMS and TQM, indicating a high level of readiness for implementation, which is necessary but not sufficient condition. A sufficient condition would presuppose taking measures in the areas of management, technology, training, motivation, etc., to create conditions for successful integration of TQM with Industry 4.0.

1. INTRODUCTION - INDUSTRY 4.0 AND TQM

TQM and Industry 4.0 are based on the concept of smart manufacturing/factory, where machines are integrated with humans through cyber-physical systems [1]. Industry 4.0 covers operational, technical, production, and social issues [2]. Industry 4.0 could be defined as the integration of automation with cyber-physical systems from previous industrial revolutions with digital data from emerging technologies such as sensors and advanced analytics techniques [3,4]. Since Industry 4.0 combines human and technological perspectives, TQM becomes an integral part of socio-technical systems [5]. As a result, TQM practices will influence the relationship between Industry 4.0 and operational performance. On the other hand, Industry 4.0 supports the efficient implementation of TQM [6]. Therefore, this mutually beneficial relationship between I4.0 and TQM underscores the importance of TQM dimensions for Industry 4.0.

TQM is a new system of practices, tools, and training for managing business in an ever-changing environment to ensure customer satisfaction [7]. However, the implementation of TQM is necessary for the integration elements to be in the most favorable relationship. Digital technology will transform conventional TQM into Quality 4.0, which refers to the digitization of TQM and its impact on people, processes, and technology [8]. Quality 4.0 is considered as a further extension of TQM into Industry 4.0. Simply put, total quality management and business excellence are modern paradigms that enable digital technologies to enhance companies' capacity to reliably produce high-quality products. [9].

Since I4.0 combines human and technological perspectives [9], TQM becomes an integral part of socio-technical systems. As a result, TQM practices will influence the relationship between I4.0 and operational performance [10,11]. On the other hand, I4.0 supports the efficient implementation of TQM. TQM is a new system of practices, tools, and training for managing business in an environment that is constantly changing to ensure customer satisfaction. However, the implementation of TQM is necessary to integrate both hard and soft aspects. Digital technology will transform conventional TQM into Quality 4.0, which refers to the digitization of TQM and its impact on people, processes, and technology. Quality 4.0 is considered as a further extension of TQM into I4.0. Total Quality Management is a modern paradigm that enables digital technologies to increase companies' capacity to reliably produce high-quality products [12].

According to the literature, Wilkinson [13] was likely the first to introduce a multidimensional view of TQM. Since then, the multidimensional approach has found wide application in the literature on critical components of TQM; however, research studies on the multidimensional perspective of TQM are still rare. Based on the above conclusion, review studies have focused on presenting a general/unidimensional perspective of TQM but have ignored the multidimensional perspective. The measurement of TQM system implementation and any potential shortcomings directly affect the efficiency of integrating TQM systems and Industry 4.0. However, there is no comprehensive approach to identifying the impact of Industry 4.0 on TQM in a detailed and comprehensive manner, although all studies have agreed that the application of Industry 4.0 positively influences quality management.

2. MEASUREMENT METHODS

Measurement allows us to gather important data based on which we define what is good and what needs improvement. Measurement allows us to see the 'invisible,' as Stuart Schrader puts it. Once the invisible forces of the process are seen, everything takes on a different perspective, as it opens the way for improvements. We measure not only the business process but also the organizational structure, motivation, management style, etc. According to Deming, the contribution of each component should be measured, as this enables the components to adapt to the changes that occur in the business system.

Measurement must be:

- Easy to conduct,
- Accessible to those who need feedback,
- Time-planned and limited.

The measurement was conducted on the following business systems:

- System A is a large business system with over 100 employees. This system has decades of experience in cigarette production, with significant production and human resources.
- Another characteristic system is business system B in the food industry with 200 employees. The system has equipment for producing juices and oils. It also belongs to the group of large business systems.
- The third characteristic analyzed system is system C in the production of paper packaging. It belongs to the group of medium-sized systems.

2.1 Factors Influencing Implementation

In this study, based on the analysis of the current state, it was determined that the quality of implementation depends least on the following factors:

- Management commitment,
- Resources,
- Motivation,
- Training,
- Costs due to internal and external deficiencies,
- Preventive costs,
- Usability and delivery time,
- Process management,
- Operational business processes,
- Supporting processes.

Each of these factors has been decomposed into elements. The structure of the factors is provided in Tables 2-10.

3. METHODOLOGICAL APPROACH TO ANALYSIS

3.1 Identification of the most influential objective

First, data on the quality objectives of the business systems were collected, and their quantification was conducted. The quantified values were normalized and assigned significance weights. Using quality objective simulation software, the significance ranking and quality level were calculated. Based on these values, the most influential objectives were identified, and their values were increased, initially for the QMS environment and later for TQM. For each increased value of the influential objective, actions required to achieve that value were defined. Values were assigned based on:

- existing state of the analyzed business systems,
- gradual improvement that can realistically be achieved,
- company resources,
- level of training for QMS and TQM,
- environment in which the business systems operate.

The most influential objectives are decomposed into three categories of goals to better understand their significance. On the other hand, the assessment of the existing state conducted for the analyzed business systems according to the requirements of the ISO 9001 standard is grouped into: management, operational, and support processes. The value for training is taken from the assessment of the existing state and highlighted as a separate category due to its importance in the implementation phase, although it is also included in the support process.

The identification of the most influential objectives, as well as the assigned values, are presented in Table 1.

Table 1. Values of the most influential goals for the analyzed business systems.

12. Product work properties	System A	System B	System C
Current value	6	7	7
Improvement	7	8	8
Desired amount of change	9	9	9
13. Product safety	System A	System B	System C
Current value	6	7	7
Improvement	7	8	8
Desired amount of change	9	9	9
14. Product reliability	System A	System B	System C
Current value	6	6	7
Improvement	7	7	8
Desired amount of change	9	9	9
15. Customer orientation	System A	System B	System C
Current value	6	6	7
Improvement	7	7	8
Desired amount of change	9	9	9
16. Quality planning	System A	System B	System C
Current value	2	2	2
Improvement	5	5	5
Desired amount of change	7	7	7
17. Workforce training	System A	System B	System C
Current value	2	3	5
Improvement	5	5	7

Desired amount of change	7	7	9
19. Quality monitoring	System A	System B	System C
Current value	4	5	3
Improvement	6	7	5
Desired amount of change	8	9	7
20. Equipment development	System A	System B	System C
Current value	3	4	3
Improvement	5	5	5
Desired amount of change	7	7	7
22. Laboratory testing	System A	System B	System C
Current value	7	9	5
Improvement	8	9	7
Desired amount of change	9	9	9
24. Inspection costs	System A	System B	System C
Current value	8	9	7
Improvement	9	9	8
Desired amount of change	9	9	9
26. Process analysis and method development	System A	System B	System C
Current value	4	5	3
Improvement	6	7	5
Desired amount of change	8	9	8
30. Scrap costs	System A	System B	System C
Current value	4	0	6
Improvement	6	0	8
Desired amount of change	8	0	9
32. Rework costs	System A	System B	System C
Current value	7	3	5
Improvement	9	5	7
Desired amount of change	9	7	9
33. Complaint costs	System A	System B	System C
Current value	6	4	7
Improvement	7	6	8
Desired amount of change	9	8	9

36. System flexibility	System A	System B	System C
Current value	5	6	5
Improvement	7	7	7
Desired amount of change	9	9	9
37. Delivery time	System A	System B	System C
Current value	6	4	7
Improvement	7	6	8
Desired amount of change	9	8	9

The values of these factors for business system A are given in tables 2-10. The calculation methodology for business systems B and C is the same.

Table 1. The factor "Management commitment" for business system A.

Factor: Management commitment	Ponder	Rating	Value	QMS	Value	TQM	Value
Dedication to the concept	0.3	5	1.5	8	2.4	10	3.0
Training	0.2	5	1.0	8	1.6	10	2.0
Communicativeness	0.2	5	1.0	8	1.6	10	2.0
Research orientation	0.1	4	0.4	7	0.7	9	0.9
Analytical skills	0.1	4	0.4	7	0.7	9	0.9
Enthusiasm	0.1	6	0.6	8	0.8	10	1.0
TOTAL			4.9		7.8		9.8

Table 2. The factor "Resources" for business system A.

Factor: Resources	*Ponder*	*Rating*	*Value*	*QMS*	*Value*	*TQM*	*Value*
Personnel	0.3	5	1.5	8	2.4	9	2.7
Finances	0.2	4	0.8	7	1.4	9	1.8
Business space	0.1	9	0.9	9	0.9	10	1.0
Equipment	0.1	8	0.8	9	0.9	10	1.0
Technology	0.1	6	0.6	8	0.8	10	1.0
Laboratory	0.2	5	1.0	8	1.6	9	1.8
TOTAL			5.6		8.0		9.3

Table 3. The factor "Motivation" for business system A.

Factor: Motivation	Ponder	Rating	Value	QMS	Value	TQM	Value
Career development	0.2	5	1.0	7	1.4	9	1.8
Communication between teams	0.2	5	1.0	7	1.4	9	1.8
Involvement in changes	0.2	7	1.4	9	1.8	10	2.0
Recognition	0.2	3	0.6	7	1.4	9	1.8
Training and education	0.2	6	1.2	8	1.6	10	2.0
TOTAL			5.2		7.6		9.2

Table 4. The factor "Management processes" for system A.

Factor: Management processes	Ponder	Rating	Value	QMS	Value	TQM	Value
4.1 Management responsibility	0.2	2.8	0.56	7.0	1.4	9.0	1.8
4.2 Quality system	0.1	3.2	0.32	7.0	0.7	9.0	0.9
4.5 Document and data control	0.2	2.4	0.48	7.0	1.4	9.0	1.8
4.13 Control of nonconforming product	0.1	5.0	0.5	8.0	0.8	10.0	1.0
4.14 Corrective and preventive actions	0.1	3.8	0.38	7.0	0.7	9.0	0.9
4.16 Quality record management	0.2	4.4	0.88	7.0	1.4	9.0	1.8
4.17 Internal quality audit	0.1	2.7	0.27	7.0	0.7	9.0	0.9
TOTAL			3.39		7.1		9.1

Table 5. The factor "Operational business processes" for system A.

Factor: Operational business processes	Ponder	Rating	Value	QMS	Value	TQM	Value
4.3 Contract review	0.1	3.2	0.32	7.0	0.7	9.0	0.9
4.4 Development management	0.2	4.0	0.4	7.0	1.4	9.0	1.8
4.6 Procurement	0.1	4.1	0.41	7.0	0.7	9.0	0.9
4.7 Customer-related processes	0.05	3.0	0.15	7.0	0.35	9.0	0.45
4.9 Process management	0.2	4.1	0.82	7.0	1.4	9.0	1.8
4.10 Monitoring and measurement	0.2	6.0	1.2	8.0	1.6	10.0	2
4.15 Handling, packaging, storage, and delivery	0.1	3.8	0.38	7.0	0.7	9.0	0.9
4.19 Servicing	0.05	3.6	0.18	7.0	0.35	9.0	0.45
TOTAL			3.86		7.2		9.0

Table 6. The factor "Supporting processes" for system A.

Factor: Supporting processes	Ponder	Rating	Value	QMS	Value	TQM	Value
4.8 Identification and traceability	0.1	4.7	0.47	7.0	0.7	9.0	0.9
4.11 Control of inspection, measuring, and test equipment	0.2	3.3	0.66	7.0	1.4	9.0	1.8
4.12 Control of monitoring and measuring devices	0.3	5.2	1.56	8.0	2.4	10.0	3
4.18 Training	0.3	2.4	0.72	7.0	2.1	9.0	2.7
4.20 Statistical techniques	0.1	2.5	0.25	7.0	0.7	9.0	0.9
TOTAL			3.66		7.4		9.3

Table 7. The factor "Costs of internal audit, internal, and external deficiencies".

Factor: Costs of internal audit, internal, and external deficiencies	Ponder	Rating	Value	QMS	Value	TQM	Value
22. Laboratory testing	0.2	7	1.4	8	1.6	9	1.8
24. Inspection costs	0.2	8	1.6	8	1.6	9	1.8
30. Scrap costs	0.3	4	1.2	6	1.8	8	2.4
32. Rework costs	0.1	7	0.7	7	0.7	9	0.9
33. Complaint costs	0.2	6	1.2	7	1.4	9	1.8
TOTAL			6.1		7.1		8.7

Table 8. The factor "Preventive costs" for system A.

Factor: Prevention costs	Ponder	Rating	Value	QMS	Value	TQM	Value
16. Quality planning	0.2	2	0.4	5	1,0	7	1,4

17. Workforce training	0.2	2	0.4	5	1,0	7	1,4
19. Quality monitoring	0.2	4	0.8	6	1,2	8	1,6
20. Equipment development	0.2	3	0.6	5	1,0	7	1,4
26. Process analysis and method development	0.2	4	0.8	6	1,2	8	1,6
TOTAL			3.0		5.4		7.4

Table 9. The factor "Usability and delivery time" for system A.

Factor: Usability and delivery time	Ponder	Rating	Value	QMS	Value	TQM	Value
12. Product work properties	0.1	6	0.6	7	0.7	9	0.9
13. Product safety	0.2	6	1.2	7	1.4	9	1.8
14. Product reliability	0.1	6	0.6	7	0.7	9	0.9
15. Customer orientation	0.2	6	1.2	7	1.4	9	1.8
36. Product flexibility	0.2	6	1.2	7	1.4	9	1.8
37. Delivery time	0.2	5	1.0	7	1.4	9	1.8
TOTAL			5.8		7.0		9.0

Table 10. The implementation value for business system A.

Factor name	Ponder	Rating	Value	QMS	Value	TQM	Value
Management commitment	0.1	5.4	0.54	6.8	0.68	9.55	0.95
Resources	0.05	5.6	0.28	8.0	0.4	9.3	0.46
Motivation	0.1	5.2	0.52	7.6	0.76	9.2	0.92
Training	0.2	2.4	0.48	7	1.4	9	1.8
Internal and external deficiencies	0.1	6.1	0.61	7.1	0.71	8.7	0.87
Prevention costs	0.1	3	0.3	5.4	0.54	7.4	0.74
Usability and delivery time	0.1	5.8	0.58	7.0	0.7	9.0	0.9
Management processes	0.1	3.39	0.33	7.1	0.71	9.1	0.91
Operational business processes	0.1	3.86	0.38	7.2	0.72	9.0	0.9
Supporting processes	0.05	3.36	0.16	7.4	0.37	9.3	0.46
TOTAL			4.18		5.99		8.91

Table 11. The implementation value for business system B.

Factor name	Ponder	Rating	Value	QMS	Value	TQM	Value
Management commitment-leadership	0.1	5.5	0.55	7.1	0.71	8.75	0.87
Resources	0.05	5.6	0.28	7.5	0.37	8.3	0.41
Motivation	0.1	5.2	0.52	7.2	0.72	9.2	0.92
Training	0.2	2.4	0.48	7	1.4	9	1.8
Internal and external deficiencies	0.1	5.7	0.57	7.2	0.72	8.7	0.87
Prevention costs	0.1	3.2	0.32	5.4	0.54	7.6	0.76
Usability and delivery time	0.1	6.2	0.62	7.5	0.75	9.0	0.9
Management processes	0.1	3.14	0.31	7.0	0.70	9.0	0.90
Operational business processes	0.1	5.07	0.50	7.7	0.77	9.5	0.95
Supporting processes	0.05	3.79	0.18	7.3	0.36	9.3	0.46
TOTAL			4.33		6.84		8.84

Table 12. The implementation values for business system C.

Factor name	Ponder	Rating	Value	QMS	Value	TQM	Value
Management commitment - leadership	0.1	5.5	0.55	7.1	0.71	8.75	0.87
Resources	0.05	6.6	0.33	8.0	0.4	9.8	0.49
Motivation	0.1	6.0	0.6	7.6	0.76	9.2	0.92
Training	0.2	2.4	0.48	7	1.4	9	1.8
Internal and external deficiencies	0.1	5.7	0.57	6.3	0.63	8.1	0.81
Prevention costs	0.1	3.8	0.38	5.8	0.58	7.8	0.78
Usability and delivery time	0.1	5.9	0.59	7.3	0.73	9.0	0.9
Management processes	0.1	3.89	0.38	7.7	0.77	9.4	0.94
Operational business processes	0.1	4.76	0.47	7.5	0.75	9.45	0.94
Supporting processes	0.05	4.98	0.24	7.6	0.38	9.6	0.48
TOTAL			4.59		7.11		8.93

The actual level of implementation of SQ on a scale from 1 to 10 for the observed business systems is obtained as the product of the coefficients of significance and the values of the implementation factors, as shown in tables 11-13.

From the tables, it follows that the current state is low (below 5) for all three systems. Analyzing the obtained results, it is evident that the implementation values are lower than required. These values indicate that there is a need for improvement in the business systems, which should be carried out gradually. It is necessary to identify the most influential goals and increase their values, first for the QMS environment and later for TQM. For each increased value of an influential goal, it is necessary to define what needs to be done to achieve that level of value.

For the journey towards TQM to be successful, it is essential to affirm strategic directions. Some of these include:

- Engage all employees.
- Implement ongoing training programs.
- Improve the quality of management.
- Define process capabilities and responsibilities for their implementation.
- Establish a system for measuring process components.
- Develop and affirm internal control systems.
- Utilize engaged resources more efficiently.
- Continuously improve technology (innovations) and shorten production cycles.
- Define quality according to global standards rather than the standards of the subject system.

Simply put, it's necessary to take measures in management, technology, training, motivation, etc., to create conditions for the successful implementation of QMS and TQM systems. Only successful TQM implementation enhances the production process by increasing flexibility, productivity, speed, and quality. Industry 4.0 serves as the foundation for adopting new business models, manufacturing processes, and other innovations.

4. CONCLUSION

The successful implementation of a quality system in a company begins with an assessment of the current quality status relative to the requirements of quality standards. This assessment is crucial because the level of quality that a company possesses can significantly influence the speed at which QMS or TQM is introduced. Since there are no established rules for data collection for the purposes of this work, the following sources of information were used:

- Analysis of the annual financial statements,
- Business expense reports,
- Travel expenses,
- Documentation on control,
- Scrap reports, etc.

During the data collection process, the expert assessments from the analyzed business systems were also valuable. The methodology conducted provides good assumptions for an objective assessment of the current state. A large number of expert questions, a wide range of evaluations, and the objectivity of assessors enabled a realistic view of the quality systems even in complex production-business systems presented in this work.

In any case, the requirements of the ISO 9000 series standards are of a much higher quality level than the quality found in enterprises that have not yet begun implementation.

Successful implementation involves detailed planning, allocation of necessary resources, defining measures and actions, as well as removing all objective and subjective obstacles in its path. Furthermore, real-time information flow from machines, objects, and workforce to and from factory management has made decision-making processes more efficient, reliable, and rapid. Connecting all parties in the value chain, including people, products, devices, and processes, with other business management solutions, is crucial.

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