Closed-Loop Quality Management Systems: Are Czech Companies Ready?

DOI: 10.12776/QIP.V26I2.1710

David Vykydal, Jaroslav Nenadál

Received: 2022-06-27 Accepted: 2022-07-12 Published: 2022-07-31

ABSTRACT

Purpose: The paper brings set of original information related to the next quality management systems development with regard to digitalisation and other features of new era. It proposes basic structure of closed-loop quality management systems (CLQMS) as a mixture of internal, external, horizontal and vertical loops.

Methodology/Approach: Comparative literature analysis, standards' analysis, brainstorming, field research, interviews and design review were used.

Findings: Information flows are counted as vital part of all advanced closed-loop quality management systems. Authors established definition of CLQMS. 209 of various requirements related to information exchange were discovered through study of ISO 9001:2015, IATF 16949:2016 and EFQM Model, version 2020. These requirements should create a basic platform for CLQMS establishing and development. Authors performed an empirical field research which. Confirmed that current readiness of Czech production companies for CLQMS implementation is insufficient, despite the automotive sector reaches a higher level of such readiness.

Research Limitation/Implication: The field research was performed in time span accompanied by stern measures caused by COVID-19. The only English language literature resources were considered for a literature review.

Originality/Value of paper: The paper brings original set of information, regarding to definition of the CLQMS, findings from special field research.

Category: Research paper

Keywords: closed-loop quality management; quality 4.0; management system; feedback loop

1 INTRODUCTION

Consistently meeting all stakeholders' requirements (especially oriented to the future) poses a permanent challenge for all types of organizations. Hence quality management systems based on various standards or excellence models will be an important part of overall management systems. Unfortunately, a lot of certified quality management systems, mainly against ISO 9001:2015 requirements are rigid, static and they do not comply with current demands on new era of digitalisation.

Zairi (2018) even argues that total quality management has become redundant. Anyway, meaning of quality management is commonly recognized. But traditional approaches to the quality management and structures of current quality management systems will have to be transformed in order to meet dramatic technological development, presented by Industry 4.0 concept. Gunasekaran, Subramanian and Ngai (2019) say that although quality management became popular in 80's of the last century, enterprises are still struggling with the concept Industry 4.0. Industry 4.0 refers to recent technological advances where internet and supporting technologies serve as a backbone to integrate physical objects, human actors, intelligent machines, production lines and processes across organizational boundaries to form a new kind of intelligent, networked and agile value chain (Schumacher, Erol and Sihn, W., 2016). A comprehensive response on Industry 4.0 in area of quality management is usually titled as Quality 4.0. Javaid et al. (2021) underline that Quality 4.0 is a central principle enabling to harmonize quality management activities with Industry 4.0's new capabilities. The Quality 4.0 is about transforming and improving organizational culture, collaboration, competency and leadership development through the application of technology (Bridges, 2021). Hundreds of articles had been published in this area during last five years analysing various aspects of Quality 4.0 concept. Jacob (2017) looks upon the Quality 4.0 as mixture of new technologies with traditional quality methods to arrive at new optimums in operational excellence, performance, and innovation. Vision and other strategic declarations focused on Quality 4.0 are mentioned as crucial prerequisite (Sony et al., 2021). Some findings from special pilot survey in which 36 quality directors from European firms testified necessity for investments and skills as one of five crucial requirements associated with the Quality 4.0 implementation (Antony, Sony and Cudney, 2020). Santos et al have already identified typical kinds of skills needed for the Quality 4.0 (Santos et al., 2021). Elg et al. (2021) underline necessity in area of cross-functional quality professionals' collaboration with IT specialists and process managers Carvalho et al. (2021) discuss key quality management practices in era of the Industry 4.0. These references are only a few examples of papers dedicated to certain features of the Quality 4.0.

Briefly to say: The Quality 4.0 is really hot and very popular topic at present. We do not want to play down this topic. On the contrary, we are aware of fact that traditional approaches to the quality planning, control, assurance and

improvement must be dramatically changed and all quality management systems, regardless they are certified or not, will have to be transformed from the point of their structures, scopes, objectives, infrastructure or people competency. Therefore, authors hope this article could be considered as a small but not useless contribution to such transformation.

2 METHODOLOGY

After necessary literature review, the authors were able to formulate three preliminary findings which led to the creation an original definition of term "closed-loop quality management system". Authors' investigation also aimed to the design of an original framework for CLQMS. Moreover, authors studied three commonly recognized international standards with aim to identify necessary information flows within CLQMS. To discover on what level of readiness for CLQMS implementation Czech production companies are a special questionnaire field survey was provided. 573 Czech production companies from various areas of business were randomly selected for data gathering. Core data gathering was based on a structured questionnaire which could be filled by electronical aid. A response rate was 21.12%. To confirm two research hypotheses, a quantitative and qualitative approach was used to the data processing. Results presented below should be understood as information inputs to the next research activities in area of the Quality 4.0 development throughout the world.

3 LITERATURE REVIEW

Some opinions regarding to the Quality 4.0 were already presented in section Introduction. Now, we focus on progressive approach frequently called mostly as „closed-loop quality management". This approach could be considered as convenient way how to adjust traditional quality management to the new era of digitalisation. The fundamental research question is: was already reached general agreement bearing on terms or structure of the closed-loop quality management?

Unlike Industry 4.0 or Quality 4.0 concepts as a whole, the various issues of the closed-loop quality management are discussed to a lesser extent. Sundaram (2018) declares the belief of organizations that traditional quality management systems are increasingly making a move towards a more future-ready. The closed-loop approach is mentioned there as suitable way. Littlefield (2014) says that closed-loop quality management essentially means connecting quality process or performance data from one area to another, always with the goal of improving quality earlier. Rutter (2021) argues: "closed-loop quality management is the manufacturing business process of proactively making all of the data and processes necessary for ensuring product quality is accessible in one central location, bringing product results from the field back for scope assessment, future issue prevention, and continuous improvement". He also

discusses some benefits, including reduced cost of quality. Such issue discussed also Jasurda (2012) despite he has limited closed-loop approach to quality management only to virtual simulations and tolerance analysis software. The economic impact is caused by possibilities when digital technologies and data analytics discover patterns otherwise impossible to detect and take preventive action in early stage of the process (Tomic, 2021). Jardine (2015) declares that for a closed-loop quality system to be truly effective, it must centralize, standardize, and streamline end-to-end business processes and quality data. This can be accomplished most successfully by digitalisation. Goulévitch (2018) presented eight examples of how closed-loop quality management systems should work, including transparency in production processes, traceability, integration with ERP systems, facilitation of lean processes, etc. Speer (2020) holds the view that: "manufacturers must establish procedures for identifying product during all stages of receipt, production, distribution, and installation to prevent failures. This is to ensure that companies are closing the loop between all pre- and post-market activities. A connected system that closes this loop between processes is known as closed-loop traceability". Some papers are dedicated to partial or special issues of the closed-loop management. For example, Franciosa et al. (2020) presents a digital twin framework with closed-loop in-process quality improvement for assembly systems. The closed-loop management in area of acquisition operations and maintenance process is discussed by Kang et al. (2019). But our investigations discovered that majority of articles are oriented at present to the development of the closed-loop management within supply chains. Authors are usually interested in area of non-conformities or returned products with respect of circular economy principles, as well as supplier's social responsibility (see Masouipour, Amirian and Sahrasian, 2017; Chen, Umya and Mancasari, 2020; Almaraj and Trafalis, 2019 and others).

On basis of literature review we are able to formulate three preliminary findings:

1. There is no unified and commonly recognized definition of the term "closed-loop quality management system". Ambiguity of explanations are evident.
2. Authors mostly pay an attention to employment different smart physical devices as sensors, robots, information systems hardware, connectivity means, etc.
3. On the contrary, problems connected with information flows are rather underestimated, despite these flows ought to be counted as vital part of all advanced closed-loop quality management systems!

4 RESULTS

Results presented in this section should be looked upon a response to the three preliminary findings identified above. They are outputs of authors research works.

Above all else, we had to create a definition of the term "closed-loop quality management system". We can launch our conception of it as follows:

Closed-loop quality management system is a part of overall organization's management system based on advanced quality management principles which enables to integrate through comprehensive information flows all quality management processes or performance data with aim to improve the organizational quality.

We do not consider this definition as ultimate declaration. On the contrary, it should be understood as a basis of a future academic discussion and refinement. But this definition has created a starting point for activities, outputs of which will be shown in following sections 4.1 and 4.2.

4.1 The Conceptual Framework of the Closed-Loop Quality Management System

As mentioned above, the information flows should be counted as an essential element of all advanced closed-loop quality management systems. In the upshot, Marsden (2019) confirms this prerequisite as he claims: "The lifeblood of quality management processes is information. Without unique, accurate, timely, complete, accessible, valid and reliable information, then these processes will fail to fully demonstrate performance" Zairi (2019) says: "The plasma of a modern eco-systems is the richness of information and the power of analytics which can guide the eco-system towards its future with more confidence". Companies use a lot of various physical and information devices which should be integrated. Sony et al. (2021) distinguish three forms of integration within the closed-loop quality management in the Quality 4.0 era:

- horizontal (which is along the entire value creation chain),
- vertical (which is alongside the organization's system),
- end-to-end (along the product life cycle).

The quality management systems should concentrate on all types of integration (Sony et al., 2021). To be a framework for Industry 4.0 implementation and assessment, this integration should be considered as a mixture of infrastructure and processes (Lara et al., 2020). Schlechtendahl et al. (2015) says the systems integration is the first step towards Industry 4.0 vision and achieving its goal. Hence, we designed a basic framework of the closed-loop quality management system (see Figure 1) with respect to these arguments.

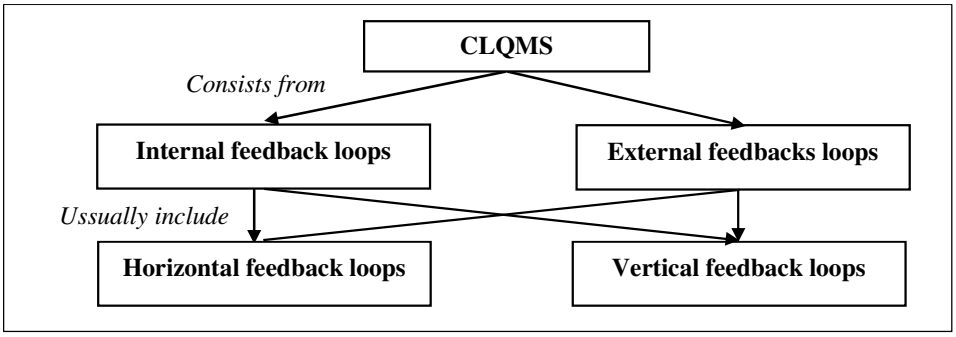

Figure 1 – Basic Framework of CLQMS

Internal feedback loops cover set of information from all organization's processes and performance indicators and it is handed down between process owners usually.

External feedback loops serve as communication tool between organizations' representatives and various external parties such as customers, suppliers, community, etc. The information flows should incorporate above all stakeholders' requirements and perceptions.

Horizontal feedback loops operate within single organizational level and support execution of different processes (production, marketing, logistics, etc.). They should describe how such processes are under control.

Vertical feedback loops integrate different hierarchical levels of the organization. They are located at least two different organizational levels and should enable an organization's strategy, policies and objectives communication, deployment and review.

In practice, these information feedback loops are mutually combinable and operate through an advanced communication means. The authors reviewed three recognized documents in area of current quality management systems: ISO 9001:2015, IATF 16949:2016 and the last version of EFQM Model (EFQM, 2019). 209 of various requirements related to the exchange of information were discovered there. A main distribution of these requirements is presented by Table 1.

Table 1 – Number of Information Feedback Loops Required by Recognized Quality Management Systems Documents (Own Work)

Information feedback loops		ISO 9001:2015	IATF 16949:2016 (in addition to ISO 9001:2015	EFQM Model, version 2020 (in addition to ISO 9001:2015 or IATF 16949:2016)	Total
Internal	Horizontal	13	10	2	25
	Vertical	27	33	22	82
External	Horizontal	14	39	37	90
	Vertical	2	6	4	12
Total		56	88	65	209

Some examples of the information feedback loops required by ISO 9001:2015 are shown by Table 2.

Table 2 – Examples of Information Feedback Loops Required by ISO 9001:2015

Information feedback loops		ISO 9001:2015 requirement	Relevant section of ISO 9001:2015
Internal	Horizontal	• Outputs from organizational context review • Results from internal audits	4.1 9.2.2
	Vertical	• Assignment of the responsibilities and authorities for relevant roles • Information related to measuring equipment that was found to be unfit for its intended purpose	5.3 7.1.5.2
External	Horizontal	• Information related to the quality policy • Information focused on customer complaints	5.2.2 8.2.1
	Vertical	• Knowledge obtained from external sources • Outputs from control and monitoring of the external provider's performance	7.1.6 8.4.3

Demands of IATF 16949:2016 or EFQM Model compared to ISO 9001:2015 basics are obvious. A comprehensive analysis bearing on real state of information flows within companies' quality management systems seem to be a chance for the next research.

4.2 Results of Empirical Field Research

As mentioned in abstract, the research of authors was also aimed to discovering a readiness level of Czech production companies for CLQMS implementation. To

reach this aim, the authors performed an empirical field research from November 2020 till March 2021.

Two basic research hypotheses were declared on this purpose:

H_1: Overall readiness level for CLQMS implementation is below-average in Czech production companies.

H_2: Czech production companies in automotive supply chain have achieved a higher level for CLQMS implementation relative the other companies.

573 Czech production companies from various areas of business were randomly selected with support of Albertina database. Data gathering was based on structured questionnaire which could be filled solely by electronical aid. The representative response was obtained from 121 companies, what means a real response rate 21.12%. Table 3 informs about companies' distribution from business area point of view.

Table 3 – Companies' Distribution from Business Area Point of View

Business area	**Number of respondents**
Automotive industry	48
Machinery	20
Textile industry	7
Metallurgy	6
Chemical industry	5
Information technologies	5
Food industry	5
Civil engineering	4
Healthcare industry	4
Electronical industry	3
Other	14
Total	121

The main findings of the research will be presented now through following figures. The horizontal axes in these figures always show a total number of respondents.

The respondents were asked if an implementation of CLQMS is included into company's strategic direction. Figure 2 shows results.

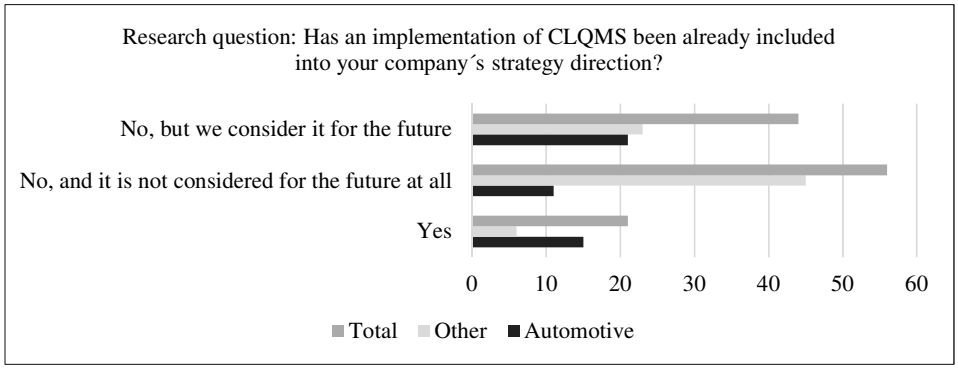

Figure 2 – Implementation of CLQMS as a Part of Czech Production Companies' Strategic Direction

The finding saying that more than 46% of Czech production companies do not consider implementation of CLQMS for the future is not quite positive.

Which stakeholders have already challenged Czech companies to the feedback digitalisation came also under scrutiny. Results are presented by Figure 3.

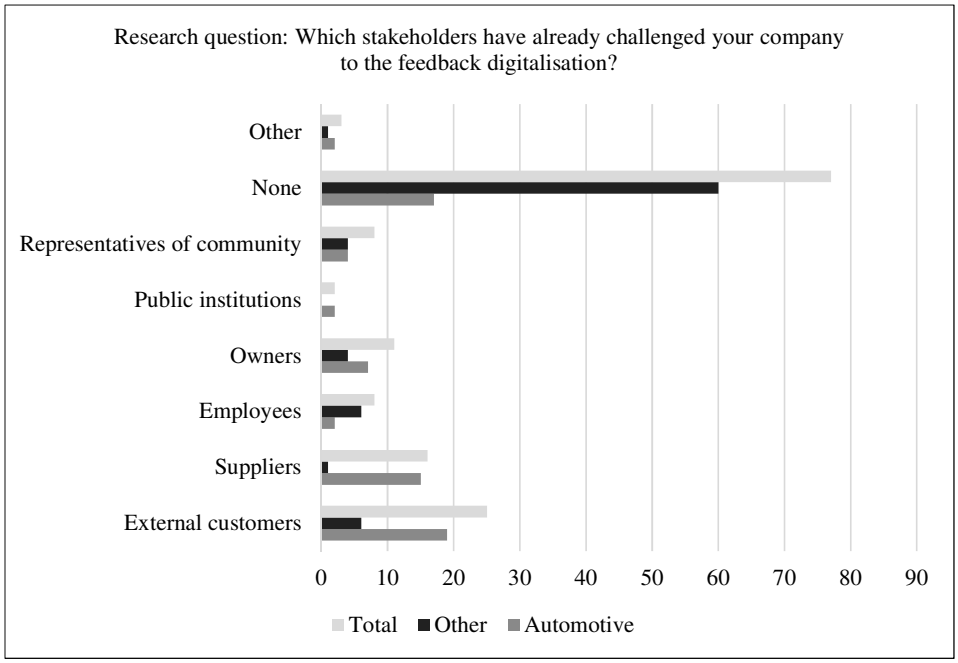

Figure 3 – Stakeholders Call to Czech Production Companies for the Feedback Digitalisation

Certain demands for the feedback digitalisation come from supply chain's links (such as suppliers or customers), especially in area of automotive industry. On the other hand, 77 respondents (what means 63.6 %) declared there is no concern

from their stakeholders in this field. It implies that stimulating context for establishing of CLQMS is mostly missing in Czech industries.

Research team was also addressed from what stakeholders Czech companies obtain feedback covering stakeholders' requirements as well as perceptions related to the companies' products. Figure 4 depicts main findings. Practically, all automotive companies gain such feedback from external customers and feedback from staff is not an exception. On the contrary: 15 companies do not get any feedback from stakeholders in spite of they are mostly certified against ISO 9001:2015 standard. This contradiction is reflective of the certification process quality.

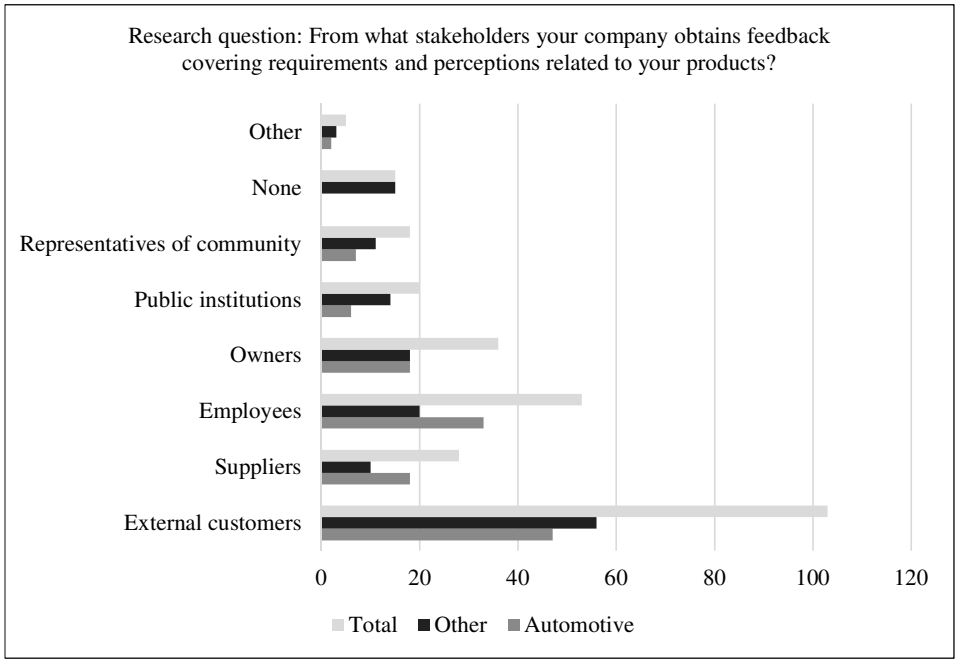

Figure 4 – Feedback Gaining from Stakeholders by Czech Production Companies

Another two questions tried to investigate expected positive effects as well as potential barriers associated with possible CLQMS implementation. Tables 4 and 5provide main findings. While opinions bear on positive effects of CLQMS implementation are relatively similar at automotive and other industries, perception of potential barriers is substantially different: production companies which are active outside the automotive supply chain perceive some barriers more urgently. Difficult co-operation and communication between quality and IT professionals poses the only exception in this case.

Table 4 – Potential Effects of CLQMS Implementation

No.	Description of potential effect	Quantity of responses		
		Automotive	Other	Total
1.	Creation of a long-term competitive advantage	31	38	69
2.	More exacting identification of the stakeholders requirements	30	38	68
3.	Reduction of products' time to market	22	36	58
4.	Enforcement of quality assurance across company processes	24	27	51
5.	Rapid interventions when quality deviations occur	30	21	51
6.	Support be-directional connections of people and processes	23	25	48
7.	Support early warning concept at design and development	19	19	38
8.	Efficient risks and opportunities management	15	17	32
9.	Better people involvement in decision-making activities	9	22	31
10.	Optimization of quality related costs	17	11	28
11.	Possibility of mass products' customization	20	4	24
12.	Enhancement of products compliance towards Six Sigma performance	8	3	11

Table 5 – Potential Barriers of CLQMS Implementation

No.	Description of potential barrier	Quantity of responses		
		Automotive	Other	Total
1.	Considerable time and capital investment	36	60	96
2.	Lack of financial resources	22	38	60
3.	Top managers mental stereotypes and unwillingness	15	34	49
4.	Necessity of a new people knowledge and competence	16	32	48
5.	Absence of long-term quality strategic direction	16	31	47
6.	Difficult co-operation and communication between quality and IT professionals	14	10	24

5 CONCLUSIONS

On basis of our investigation the following conclusions should be in place:

- The field research confirmed both research hypotheses declared in section 4.2. The current readiness of Czech production companies for CLQMS implementation is insufficient, despite the automotive sector reaches a higher level of such readiness.
- The finding saying that nearly 50% of Czech production companies do not consider implementation of CLQMS for the future is warning signal with regard to the future development.
- Respondents are aware of important positive impacts of CLQMS implementation, especially in area of companies' agility and overall performance.
- Due to potential barriers of CLQMS implementation, the current perception of Czech managers is not far away findings presented by Küpper et al. (2019) as a results of special study conducted by Boston Consulting Group. Because this study confirmed that technology is the only one piece of a broader quality transformation that must also focus on people and skills.
- On the whole: The Quality 4.0 concept is in progress, as well as development of the closed-loop quality management systems.

We are sure the Czech production companies will have not afford to ignore the Quality 4.0 concept as, perhaps, the quality management transformation is not only opportunity, but strong requirement how to adapt any company to the new industrial reality.

Authors see three key prerequisites how to improve the readiness for CLQMS at Czech companies:

1. To declare, implement and develop their vision focused on CLQMS and clearly communicate this vision internally and externally.
2. To determine and release the resources needed for CLQMS establishing, maintenance and continuous improvement.
3. New skills acquiring for all relevant roles and massive support of mutual cooperation between quality and information technology professionals.

ACKNOWLEDGEMENTS

This work was supported by the European Regional Development Fund under grant "A Research Platform Focused on Industry 4.0 and Robotics in the Ostrava Agglomeration" project No. CZ.02.1.01/0.0/0.0/17_049/000845 and VŠB-Technical University of Ostrava.

This research was also funded by the specific research project No. SP 2022/72 "Development of selected approaches, methods and tools for quality management in the context of Quality 4.0 concept adaptation" which was solved at the Faculty of Materials Science and Technology, VŠB-Technical University of Ostrava, with the support of the Ministry of Education, Youth and Sports, Czech Republic.

REFERENCES

Almaraj, I.I. and Trafalis, T.B., 2019 An integrated multi-echelon robust closed-loop supply chain under imperfect quality production. *International Journal of Production Economics*, [e-journal] 218, pp.212-227. DOI: 10.1016/j.ijpe.2019.04.035.

Antony, J., Sony, M. and Cudney, E., 2020. Quality 4.0: Motivation and Challenges from a pilot survey in Europeans firms. *The Future Factory*, [online] Available at: <https://www.thefuturefactory.com/blog/53> [Accessed 06 November 2021].

Bridges, M., 2021. *11* Pillars of Quality 4.0 Framework. *Flevyblog*, [online] 15 February. Available at: <https://flevy.com/blog/11-pillars-of-quality-4-0-framework/> [Accessed 13 December 2021].

Carvalho, A.V., Enrique, D.V., Chouchene, A. and Charrua-Santos, F., 2021. Quality 4.0 An Overview. *Procedia Computer Science*, [e-journal] 181, pp-341-346. DOI: 10.1016/j.procs.2021.01.176.

Chen, C.-K., Ulya, M.A. and Mancasari, U.A., 2020. A Study of Product Quality and Marketing Efforts in Closed-Loop Supply Chains with Remanufacturing. *IEEE Transactions on Systems, Man and Cybernetics: System,* [e-journal] 50(12), pp.4870-4881. DOI: 10.1109/TSMC. 2018. 2883984.

EFQM (European Foundation for Quality Management), 2019. *The EFQM Model*. Brussels: EFQM.

Elg, M., Birch-Jensen, A., Gremyr, I., Matin, J. and Melin, U., 2021. Digitalisation and quality management: problems and prospects. *Production Planning & Control,* [e-journal] 32(12), pp.990-1003. DOI: 10.1080/09537287.2020.1780509.

Franciosa, P., Sokolov, M., Sinha, S., Sun, T. and Ceglarek, D., 2020. Deep learning enhanced digital twin for Closed-Loop In-Process Quality Improvement. *CIRP Annals – Manufacturing Technology,* [e-journal] 69, pp.369-372. DOI: 10.1016/j.cirp.2020.04.110.

Goulevitch, V., 2018. Eight examples of a properly working closed-loop quality system. *Control Engineering,* [online] 09 January. Available at: <https://www.controleng.com/articles/eight-examples-of-a-properly-working-closed-loop-quality-system> [Accessed 03 November 2018].

Gunasekaran, A., Subramanian, N. and Ngai, W.T.E., 2019. Quality management in the 21 century enterprises: Research pathway towards Industry 4.0. *International Journal of Production Economics,* [e-journal] 207, pp.125-129. DOI: 10.1016/ijpe.2018.09.005.

IATF (International Automotive Task Force), 2016. *IATF 16949 Quality management systems requirements for automotive production and relevant service part organizations.* London: AIAG.

ISO (International Standards Office), 2015. *ISO 9001 Quality management systems - Requirements.* Geneve: ISO.

Jacob, D., 2017. What is Quality 4.0.? *LNS Research,* [online] 26 July. Available at: <https://blog.lnsresearch.com/quality40> [Accessed 21 March 2020].

Jardine, J., 2015. Closed-Loop Quality Management Connecting the Value Chain. *MasterControl,* [online] 24 March. Available at: <www.mastercontrol.com/gxp-lifeline/closed-loop-quality-management-connecting-the-value-chain> [Accessed 17 November 2020].

Jasurda, D., 2012. Closed-Loop Quality Management Minimizes the Cost of Quality. *Quality Digest,* [online] 6 June. Available at: <https://www.qualitydigest.com/inside/quality-insider-article/closed-loop-quality-management-minimizes-cost-quality-060612> [Accessed 17 June 2021].

Javaid, M., Haleem, A., Singh, R.P. and Suman, R., 2021. Significance of Quality 4.0 towards comprehensive enhancement in manufacturing sector. *Sensors International*, [e-journal] 2, pp.1-13. DOI: 10.1016/j.sintl.2021.100109.

Kang, L., Shang, Y., Liu, X., Sun, Li, Z., Zhang, M., and Wu, G., 2019. Closed loop management system framework of acquisition operations and maintenance based on data homology management. *Journal of Computational Methods in Sciences and Enginnering,* [e-journal] 19(S1), pp.S55-S60. DOI: 10.3233/JCM-191009.

Küpper, D., Knizek, C., Ryeson, D. and Noecker, J., 2019. Quality 4.0 Takes More Than Technology. *BCG Boston Consulting Group*, [online] 20 August. Available at: <https://www.bcg.com/publications/2019/quality-4.0-takes-more-than-technology> [Accessed 04 February 2020].

Littlefield, M., 2014. Closed-Loop Quality Management: What You Need to Know About It. *iBASEt,* [online] 06 June. Available at: <www.ibaset.com/blog/closed-loop-quality-management> [Accessed 12 December 2018].

Marsden, P., 2019. *Digital Quality Management In Construction*. New York: Routledge.

Masouipour, E., Amirian, H. and Sahrasian, R., 2017. A novel closed-loop supply chain based on the quality of returned products. *Journal of Cleaner Production*. [e-journal] 151, pp-344-355. DOI: 10.1016/j.clepro.2017.03.067.

Pérez-Lara, M., Saucedo-Martínez, J.A., Marmolejo-Saucedo, J.A., Salais-Fierro, T.E. and Vasant, P., 2020. Vertical and horizontal integration systems in Industry 4.0. *Wireless Networks* [e-journal] 26(1), pp.4767-4775. DOI: 10.1007/s11276-018-1873-2.

Rutter, J., 2020. What Is Closed-Loop Quality Management? Propel, [online] 13 November. Available at: <https://www.propelplm.com/blog/What-is-closed-loop-quality-management> [Accessed 3 October 2021].

Santos, G., Sá, J.C., Félix M.J., Barreto, L., Carvalho, F., Doiro, M., Zgodavova, K. and Stefanović, M., 2021. New Needed Quality Management Skills for Quality Managers 4.0. *Sustainability*, [e-journal] 13(11), pp.6149. DOI: 10.3390/su13116149.

Schlechtendahl, J., Keinert, M., Kretschmer, F., Lechter, A. and Verl, A., 2015. Making existing production systems Industry 4.0 ready: Holistic approach to the integration of existing production systems in Industry 4.0 environments. *Production Engineering,* [e-journal] 9, pp.143-148. DOI: 1007/s11740-014-0586-3.

Schumacher, A., Erol, S. and Sihn, W., 2016. A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises. *Procedia CIRP,* [e-journal] 52, pp.161-166. DOI: 10.1016/j.procir.2016.07.040.

Sony, M., Antony, J., Douglas, J.A. and McDermott, O., 2021. Motivations, barriers and readiness factors for Quality 4.0 implementation: an exploratory study. *TQM Journal,* [e-journal] 33(6), pp.1502-1515. DOI: 10.1108/TQM-11-2020-0272.

Speer, J., 2020. *3* Reasons Why Closed-Loop Traceability Is a QMS Must. *Greenlight Guru*, [online] 27 September. Available at: <https://www.greenlight.guru/blog/losed-loop-traceability-qms> [Accessed 30 October 2021].

Sundaram, K., 2018. *Quality in the Future of Manufacturing. A Frost & Sullivan White Paper.* [pdf] Siemens. Available at: <www.plm.automation.siemens.com/media/global> [Accessed 04 March 2020].

Tomic, B., 2021. Speaking of Quality: Quality 4.0 and Quality Improvements. *Quality Magazine*, [online] 8 September. Available at: <https://www.qualitymag.com/articles/96673> [Accessed 06 December 2021].

Zairi, M., 2018. *Super Excellence. The Path to Sustainable Superior Performance.* Keighley: ECBPM Publishing House UK.

Zairi, M., 2019 *Leading into the Future through Excellence. An Assessment Guide*. Keighley: ECBPM Publishing House UK.

ABOUT AUTHORS

David Vykydal[0000-0002-6669-9614] (D.V.) – Asist. Prof., VSB-Technical University of Ostrava, Faculty of Materials Science and Technology, Ostrava, Czech Republic, e-mail david.vykydal@vsb.cz.

Jaroslav Nenadál[0000-0003-1526-8694] (J.N.) – Full Prof., VSB-Technical University of Ostrava, Faculty of Materials Science and Technology, Ostrava, Czech Republic, e-mail jaroslav.nenadal@vsb.cz.

AUTHOR CONTRIBUTIONS

Conceptualization, J.N. and D.V.; Methodology, J.N. and D.V.; Validation, D.V.; Formal analysis, J.N. and D.V.; Investigation, J.N. and D.V; Resources, J.N.; Data curation, J.N. and D.V; Original draft preparation, J.N. and D.V; Review and editing, J.N. and D.V; Visualization, J.N. and D.V.; Supervision, J.N.; Project administration, D.V.; Funding acquisition, J.N. and D.V.

CONFLICTS OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.