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ORIGINAL RESEARCH PAPER

Three-dimensional QCD framework of supply chain

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ABSTRACT

This study focuses on the supply chain actors' QCD framework. The authors present an innovative tool that illustrates the operating system of different actors in the supply chain by combining virtual and physical reality. The study aims to present and "visualize" the QCD coherence system with the help of the PaTeNt© – QCD spatial model. The study, therefore, focuses on the supplier, the central company; the relationship between the supply chain actors and the QCD framework, which is suitable for the agile, proactive collaboration.

The parts of the model, which is the result of the development:

- the elements of quality,
- the elements of cost,
- the elements of delivery.

The development of the model was brought to life by the tasks which need to be solved and this model helps the understanding and transparency during the work.

KEYWORDS

supply chain management, model, QCD, illustration

1. INTRODUCTION

The model helps to define the QCD approach and context system in relation to the supply chain actors and in particular to identify their relationship by mapping the five tetrahedron networks – the physical-spatial of the model.

The starting point of the PaTeNt © – QCD model was also used in other respects. It was first used in the analysis of competency skills. Subsequently, PaTeNt © - JD5T - supported the spatial presentation and visualization of job descriptions [1, 2] and was then part of the EcoMode international research [3], and the PaTeNt©- SESC – short supply chain supplier evaluation model [4]. These models are well applicable in research facilities, educational institutions, and the public and competitive sectors in a given functional area. The model is registered in the Hungarian Patent Office and it is currently under design protection. (on the 90806 registration number according to the D0500121 application number.)

However, this model composed of 5 tetrahedrons is not only suitable for structuring and systematizing the factors but also provides an opportunity to determine the central factors and to detect and illustrate the relationships between the factors.

The approach of the "vision" of reality, as it is known, is particularly important in art too, but it is also significant in the sciences. "The most important thing is to see the individual factors and the connections that arise between them, because then we ourselves get into another dimension" [5]. Recently, there has been a growing demand for illustration, "vision".

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In the sciences, decision cubes are suitable for this. These multidimensional "columns" store pre-collected data/information, allowing quick queries for different purposes. Thus, they make the data and the information obtained from it visible. The PaTeNt© - QCD model serves a similar purpose.

The presented PaTeNt© - QCD model was developed within the framework of a special, multidimensional data model. The spatial model presented in this study demonstrates supply chain actors based on the QCD triple unit.

2. INTRODUCTION OF BASIC MODEL

The development of the PaTeNt© model was initiated by the tasks that need to be solved in practical life. In connection with various research a wide range of structures, details, etc., relevant data, knowledge need to be collected. These different data have made and make it necessary to create a multidimensional spatial model [6], through which the data structure and their interactions can be seen; it is possible to form a conceptual scheme about the available data.

The general purpose and possibilities of the PaTeNt© model can be summarized as follows:

- the conceptual schema for researchers and practitioners;
- the data structure, structure rethinking, visual support, data, factors, dimensions with different depth and details;
- visualization of complex relationships of multidimensional datasets, i.e. seeing and showing relationships;
- "holding" data, information, seeing through relationships;
- easy presentation of relationships and exploration of relationships, founding the ability to analyze;
- convertible views, rotatability, the model can be transformed into different shapes, so the illustration of the relationships can be realized in the case of overlapping pages;
- effective extension using multiple tetrahedrons or fractals;
- tracking changes (reloading data-transiting changes);
- determination of research topics, educational materials, central element(s) of corporate governance;
- exploring cause-effect, part-whole relationship, exploring interacting factors, logical connections;
- exploring horizontal, vertical segmentation in the data structure;
- contact crosslink;
- founding the data structure of a multidimensional data model [6, 7].

The outstanding features of the PaTeNt© basic model are presented below in relation to the applications of the model.

The outstanding features which are going to be presented according to [8]:

1. The model is a conceptual schema.
2. The model is suitable for defining (a) central element(s).
3. The model is suitable for exploring the cause-effect, part-whole relationship, and demonstrating interacting factors, logical connections.
4. With the help of the model the horizontal, vertical dispersion can be illustrated.
5. The model can be transformed into special shapes through mobility.
6. The model is a contact crosslink that can also be thought of as a multidimensional data.

2.1. Conceptual schema

The model forms a conceptual scheme between the different data and factors in such a way that it is suitable for structuring the data and allows systematization according to the different aspects suitable for the topic. Tetrahedrons, as separate units, are suitable for the separation of the factors and, at the same time, for the exploration of the connections between them by connecting them.

2.2. Defining the central element(s)

The model is suitable for defining central elements and factors. The central element/s of the model, the elementary unit of the system being one, two, or more central tetrahedrons, are attached to its edges.

The determination of the central element can be accomplished by attaching additional related tetrahedrons to the corresponding edges. In the example shown in Fig. 1, the focus is on the person and the business goal.

2.3. Logical connections of model

The matching pages interact with each other, there is a logical connection between the page contents. Thus, the

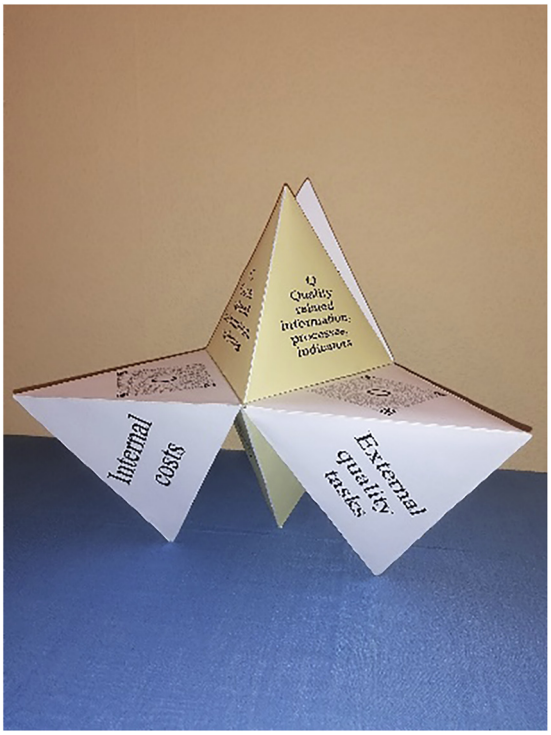

Fig. 1. The model is suitable for defining central elements and factors (*Source*: Authors' compilation)

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model is suitable for exploring and demonstrating cause-effect, part-whole relationships. It clearly and illustratively depicts – and by its rotatability – determines the factors that interact and influence each other, and it is suitable for mapping the relationships between them. Of course, the data should be placed in the model accordingly.

The model is suitable for exploring logical relationships, i.e. it can show what kind of "whole" the given factors form and what parts they consist of (Fig. 2).

Figure 2 shows an application example for displaying the relationships explored during given research, for presenting the system between the factors of a spatial job description. The shaping of the groups can be well observed. This specific division is not necessary and general, it seemed appropriate during the given research work. It can be seen that several classifications can be set up for the functions at the same time.

2.4. Horizontal, vertical dispersion

The model can be apprehensible as a "contact crossref" too, that, utilizing the special shape of tetrahedrons, can also be used to illustrate horizontal and vertical segmentation. Figure 3 shows that by arranging the contents side by side (e.g. responsibilities), the horizontal contents can be illustrated, by displaying the contents on top of each other the vertical division can be presented (e.g. activities, task, function, process, business goal). By systematically applying this structure, the relationships between factors can be visualized.

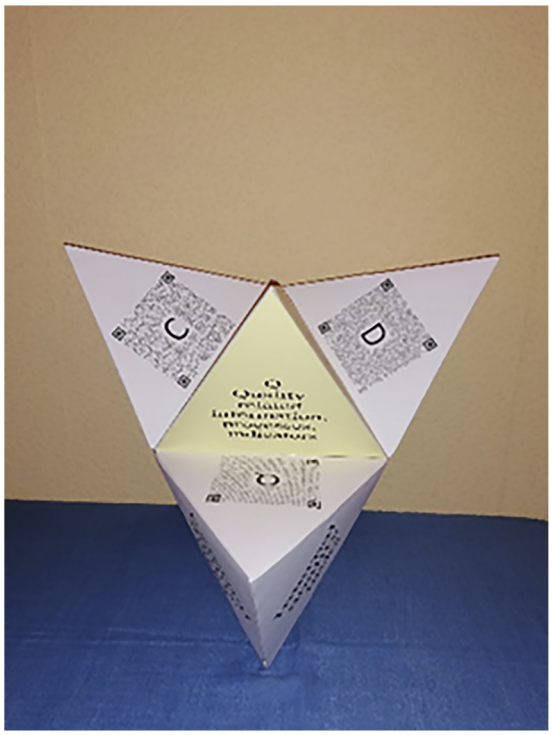

Fig. 2. The model is suitable for exploring cause-effect, part-whole relationship
(*Source*: Authors' compilation)

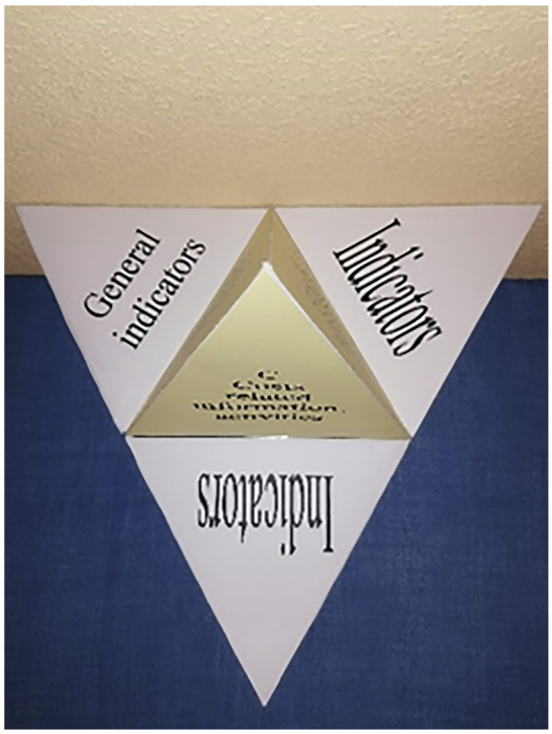

Fig. 3. The horizontal, vertical demonstration of the dispersion of the model
(*Source*: Authors' compilation)

2.5. Special shapes through mobility

The model can be transformed into special shapes in terms of its formal appearance and mobility, which shapes are suitable for expressing the relationships between the content placed on the pages. Proper positioning of the edges shows the relationship between each aspect. This layout provides a conceptual scheme for highlighting and mapping the importance of relationships.

The connection points of the model, and thus its mobility in the special direction, are an important unique feature of the spatial model – it is important that the profiles at which edges connect and thus into what other shapes it can be transformed. In this way, it is possible to show more and more links between the "contents" indicated on the page or between the "contents" of the pages belonging to the peaks which are aligned by rotation (Fig. 4).

2.6. Contact crosslink

From a tetrahedron as an elementary unit, several tetrahedrons can be connected to a larger system. From the connections, chains and networks can be formed, which results in an efficient extension of the model. Thus, the model helps to rethink the data structure when different depth and detailed data are available.

The production of the model is possible in several ways. The implementation can be physical – plastic, paper, metal, etc. – or imaginary: software. In this case, the 3D barriers can be solved and several more aspects can be considered. It

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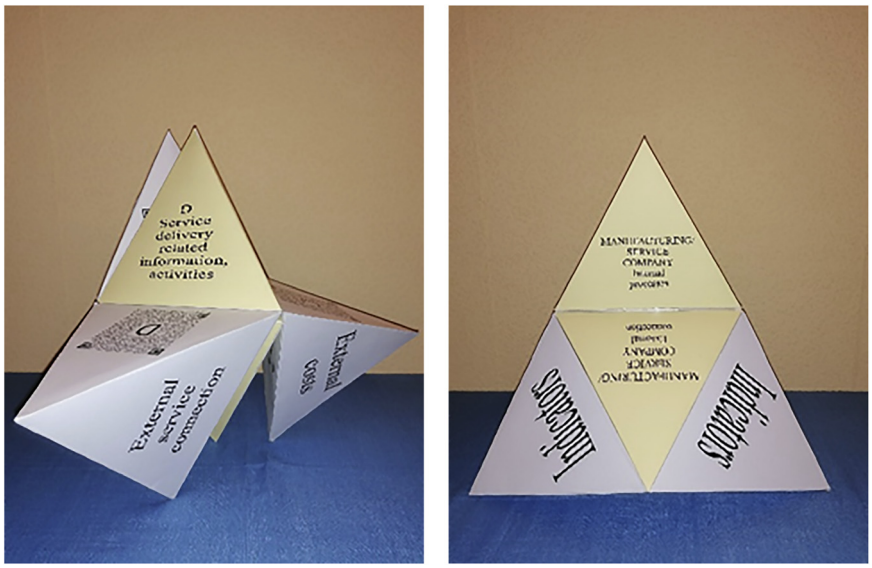

Fig. 4. The model can be transformed into special shapes
(*Source*: Authors' compilation)

is possible for many individuals to get to know the model at the same time, or even by teleworking.

3. ADAPTATION OF QR CODE IN THE QCD MODEL

Modern logistics and manufacturing are now unthinkable without identification technology and automation. Accordingly, several technologies have evolved in these areas: from simple barcodes to smart labels – from simple data to artificial intelligence [9].

Communication between supply chain participants is the top priority. The exchange of information is essential between actors, regardless of the company, which can be either a production or a service company. In the case of production companies, the related information about the product (product name, price, when, where it was manufactured, warranty, raw material information, etc.), at a service company for example in the case of airlines, the service provider may include passenger and flight information for a flight ticket or personal information for a concert or cinema ticket.

For the QCD model, the Quick Response (QR) code is chosen. QR codes are graphic signals that can be read with a QR reader or by a smartphone camera and guide a person to a website, video, or document. The advantage is that the user does not have to enter the web address or information on the website URL.

Quick Response (QR) codes are two-dimensional barcodes that are becoming new norms for users, helping them reach their partners, and providing relevant online access to relevant content in a fast, user-friendly way. Educational institutions are constantly using these 21st-century tools as a way to engage key stakeholders, i.e. students. Scanning the code takes the user into an online digital world [10, 11].

Usage of QR code became necessary due to the following aspects:

- QR code is a free open standard.
- It does not require a product ID-readable device (separate scanner for the barcode), it can be read quickly and easily with a smartphone.
- Two-dimensional barcodes connect Internet content and real objects, making it possible to connect the virtual knowledge space and the real world.
- A good feature is that it can take a photo or scanned image from any direction, it does not need to worry about the correct orientation of the code, the system will automatically detect the correct direction.
- The information that can be displayed on each surface of the tetrahedron is short, only keywords can be displayed, by reading the QR code it is possible to present further detailed descriptions, contexts, and interpretations of the keywords.
- During the presentation of the special shape, not only the illustration but also the interactivity and the active participation of the audience can attract attention.
- The code points to a link, the content of which can always be updated to students in case of constant maintenance and care.
- QR code is very popular among the younger generation.
- It can be part of the education, the theoretical material can be easily linked and the knowledge can be deepened with the QR code used in the model.

To use QR codes, a smartphone that has a QR code reader and an internet connection are needed. The QR code reader is usually available for free download from applications, and certain phones already have a built-in QR code reader [12].

Response code technology of acceptance and use has become more widespread in recent times. The company

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executives surveyed see QR codes primarily as a technology to increase the benefits of both strategic and communication with customers, thereby increasing the company's efficiency [13].

According to the research, users were asked whether the use of QR codes in education was favourable in their experience, had an effect on learning, easier understanding of the curriculum. If so, what were the parameters and components that helped learning? All participants see a positive effect: the majority of participants because of attractiveness and visualization, and many users because of updatable information and direct leading [14].

The combination of the model and the QR code makes the theoretical curriculum tangible and interactive.

4. GENERAL INTRODUCTION OF THE QCD MODEL

In the case of production and service companies, the material and information flow from the raw material supplier through the production process to the end-user are monitored throughout all phases of the logistics process.

As one of the main goals of companies is to increase the added value of the product by improving performance, customer confidence, companies are paying more and more attention to the entire supply chain [15].

The competitiveness of the supply chain can only be maintained if the QCD triple unit is continuously developed. Proper use of the QCD unit as one of the basic elements of the kaizen can result in performance improvement [16].

The QCD unit (Fig. 5) is built from the dimensions of quality, cost, and delivery. "Q," quality is very often customer-defined, one of the most important, necessary but not sufficient dimensions of a business relationship. The second dimension, "C," is cost, which involves realizing the output of a product or service to meet customer needs. "D" means delivery, product, or service to the customer.

The QCD dimensions are very significant both internally and externally in the supply chain, from the perspective of supplier and customer relationships.

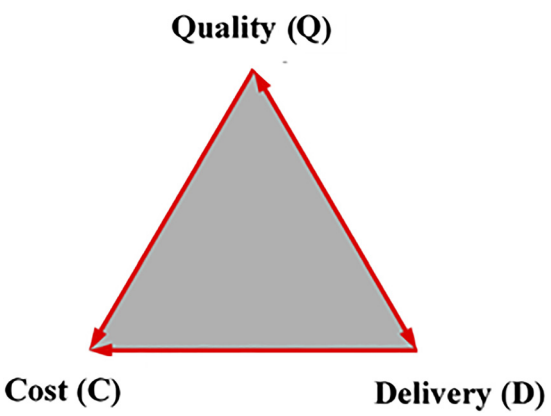

Fig. 5. QCD triangle
(*Source*: Authors based on British automobile sector developed vision)

At the same time, not only does the production/service company need to have the right QCD dimensions, but compliance with this field is also important and prioritized for customers and suppliers in this rapidly changing environment [17].

Proper access to the QCD unit is also influenced by the appropriate product, process, and organization (PPO) [18].

The development of the QCD unit can also be supported by various indicators [19], but other evaluation processes may also support the monitoring of progress [20, 21]; it is not uncommon for even a contract between business partners to fix a review of the QCD [22].

The rationality-based design between the two QCD models in [23] may lead to different but high performance. Toyota's manufacturing system was developed on the premise that the control mechanism shown in [23] outperforms its modular manufacturing system shown in [23], specifically in its system for developing production capacity [23].

The QCD (quality, cost, delivery) dimensions can be extended with service and environment factors, so in this case, we can talk about a QCDSE framework [24], however, with a well-defined QCD framework, it is not easy to convince management to integrate additional dimensions, whether social or environmental, to improve costs [25], although sustainability [26] may be necessary to maintain competitiveness. In the present model, we examine the QCD framework.

Industry 4.0 actually covers the entire supply chain, comprehensive automation, and digitization. Which can apply to either a physics or a virtual system. Coordinating different tools and applications helps companies grow faster and provide effective decision support [27].

The ever-changing technological revolution currently requires the formation of organizational changes, the continuous change and fine-tuning of business and corporate relations [28].

It is important to have an overall view of the relationships and company connections and the expected consequences and effects of the decisions at the management level.

4.1. Internal relationship system

According to the aspect of view of the internal processes of the production/service company, maintaining the QCD balance is determinant, because if the 3 conditions are not in line, the internal process of the company does not work properly. For example, if the cost of the product is on the planned level, and the service or delivery is on time, but there is a quality defect in the product, then that product cannot be sold or can only be sold below the planned price.

In the production, the transportation delays between the machines can be analyzed and optimized. There are more methods and strategies to find the best solution and result [29].

4.2. External relationship system

By developing a new or existing product, the first actor in the supply chain is to inform the supplier as early as possible and to take an active part in the processes, as it affects the lead time,

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turnover, time to market, or development costs of the company's product and the efficiency of the whole process [30].

QCD symmetry is also relevant for an external relationship, if the ratio shifts it can lead to customer problems or dissatisfaction. For example, if the cost and delivery are of the right standard, but the quality is not the expected level, then we cannot talk about customer satisfaction. However, if the quality and price are right, but the delivery is delayed or not to the given address, we can still talk about a loss of customer confidence. It is therefore very important to maintain this balance, which needs to be addressed as a matter of priority.

The spatial model of the QCD correlation system is able to define the main processes. In this case, the focus is on the corporate processes and their relationships. The spatial description is suitable for modelling by exploring logical relationships, i.e. it can show what kind of "whole" the given factors form and what parts they consist of. Therefore, the model can be apprehensible as a "contact crossref" too, that, utilizing the special shape of tetrahedrons can also be used to illustrate horizontal and vertical segmentation.

The model can be transformed into special shapes in terms of its formal appearance and mobility, and thus it is perfectly suitable for expressing the relationships between the content placed on the pages.

The connection points of the model, and thus its mobility in the special direction, are an important specification of the spatial QCD processes, that is, it is important that the profiles at which edges connect and thus into what other shapes it can be transformed, thus showing more and more links between the "contents" indicated on the page or between the "contents" of the pages belonging to the peaks which are aligned by rotation.

Proper alignment of the edges creates the connection between each aspect. This arrangement forms a conceptual scheme for finding and mapping relationships.

The dimensions of Supplier Relationship Management (communication, cooperation, trust, atmosphere and adaptation) have a significant, positive impact on performance. In the service sector, it analyzed this relationship and impact on the hospital system [31].

Accurate knowledge of customer needs and the transmission and communication of these features and requirements to suppliers is key. Continuous supplier performance measurement can keep the requirement of the end user of the supply chain [32].

Not only getting to know the company's relationship system is key, but even the physical and cyber relationships where the organizational departments form a coordinated unit, thus implementing communication, information exchange, automated systems, other processes, groups, individuals. This environment is the foundation of the smart industry [33].

5. THE SPATIAL QCD MODEL DESCRIPTION

In order for a production or service company to be able to meet the constantly changing market needs, a well-regulated system is needed. A transparent system is needed for all actors in the entire supply chain. Well-thought-out and planned processes are needed to design the structure.

Given that all sides of the 3D model (Fig. 6) are only visible in spatial representation at a time, the contents of each tetrahedron are presented below (Figs 7–13).

The starting point of the model is the production/service company, to this central element the internal QCD processes of the company and the QCD processes and metrics of its external relations (both on the supplier and customer side) are connected. These are implemented through processes. The different functions of QCD appear in the segmentation according to the processes. Specific metrics, tasks, and activities can be assigned to the elements of the QCD framework (Fig. 7). Due to the rotation mechanism to be described later, these elements appear on the sides of two tetrahedron.

The two main units of the spatial QCD model – the internal and external processes – are connected by the three main groups:

- Q – quality part dimension processes and indicators
- C – cost part dimension processes and indicators
- D – delivery part dimension processes and indicators

The building blocks of these groups are structured on three to three sides of a tetrahedron. A truly successful company needs to think about a new complex control system that will dazzle its customers, but provide the quality of the goods demanded by the customer at the right time and in all cases. The most important task for customers with excellent QCD (Quality, Cost, Delivery) in a constantly changing industrial environment is to create a new system that allows for flexible changes in the production process, taking into account high quality requirements [17, 34].

5.1. Q – Quality dimension tetrahedron structure

The tetrahedron representing the first group connected to the two central tetrahedron presents the content specification of the quality part. The units of content specification of the quality part are presented and segmented on 3 sides of a tetrahedron (Fig. 8).

A detailed description of the quality tetrahedron can be found in a document available by reading the QR code (Fig. 9). The document details the basic definitions and definitions, a detailed description of the tasks and indicators on each side of the tetrahedron.

5.2. C – Costs dimension tetrahedron structure

„Logistics have a variety of different impacts on an organization's financial performance. Logistics has traditionally been seen as an operational necessity that cannot be avoided; however, a good logistics operation can also offer opportunities for improving financial performance." [35].

The tetrahedron representing the second group connected to the two central tetrahedron presents the content specification of the cost part. The units of content specification of the cost section are presented and segmented on 3 sides of a tetrahedron (Fig. 10).

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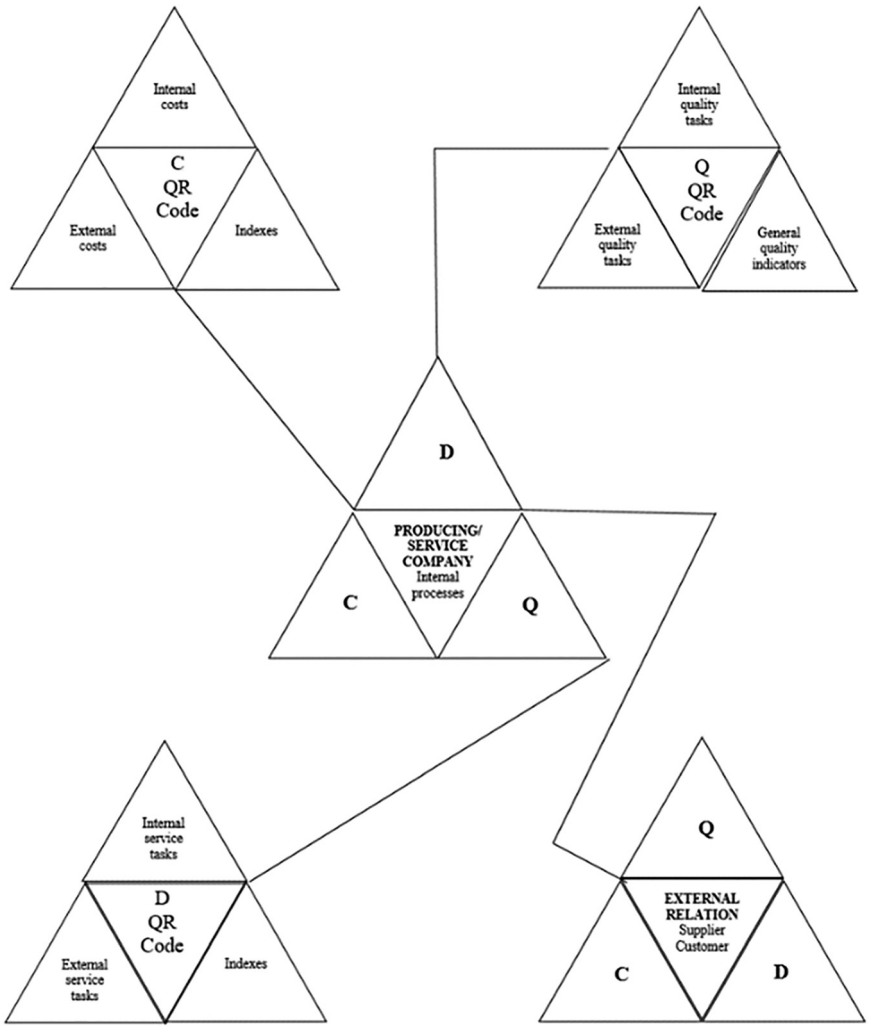

Fig. 6. An overview demonstration of the 3D QCD description
(*Source*: Authors compilation)

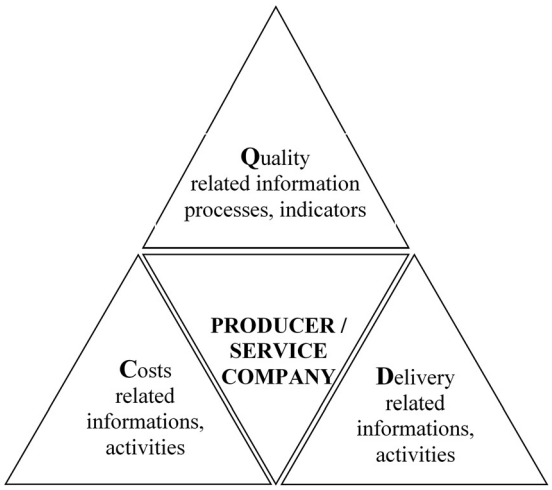

Fig. 7. Production/service company internal QCD connection
(*Source*: Authors compilation)

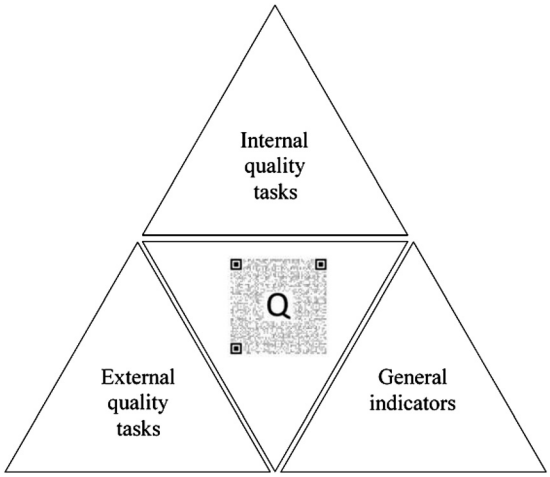

Fig. 8. Quality specification parts
(*Source*: Authors compilation)

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Fig. 9. QR code of quality system description
(*Source*: Authors compilation)

Fig. 11. QR code of cost system description
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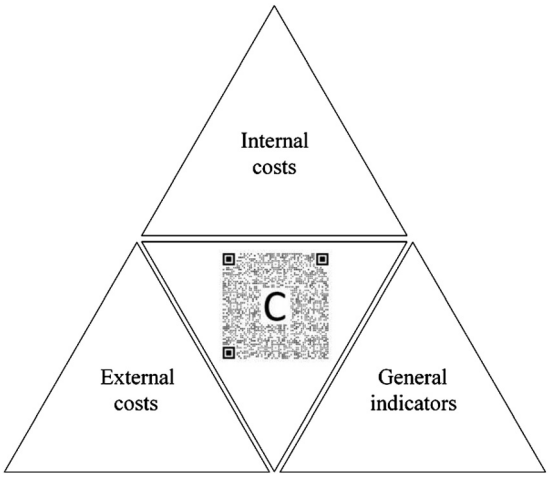

Fig. 10. Cost specification parts
(*Source*: Authors compilation)

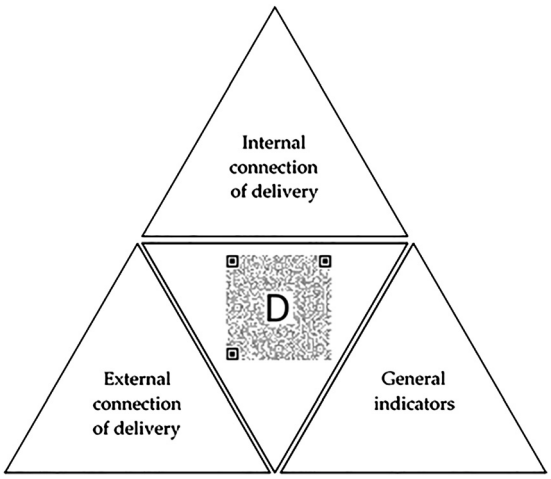

Fig. 12. Delivery specification parts
(*Source*: Authors compilation)

The processes of supply chain management and the quality part have been embedded in the operational processes of companies almost from the very beginning. In addition to the organizational and operational aspects, quality aspects may extend to technical devices, techniques or technology. For some industries, there are separate systems of standards that focus on critical core competencies in the field [36].

A detailed description of the tetrahedron related to the cost elements can be found in a document available by reading the QR code (Fig. 11). The document details the basic definitions and definitions, a detailed description of the tasks and indicators on each side of the tetrahedron.

5.3. D – Delivery dimension tetrahedron structure

The supply process is an integral part of the supply chain and has an impact on the efficiency of the entire process. In the case of transportation systems, it is also necessary to follow the principle of continuous development. Nowadays it is needed for the existence of transport information systems technology. In the delivery of goods, there needs to be an exchange of information between those involved in the transport process including customers as well [37].

Continuous improvement in transportation and logistics is needed to enable transportation companies and systems to keep up with technological change and thus be able to compete with other companies in the market [38].

The tetrahedron, which presents the third group of accessories connected to the two central tetrahedron, presents the accessories of tasks and indicators related to services and transport processes. The units of the technical specification of the service sub-process description are presented and segmented on the 3 sides of the tetrahedron (Fig. 12).

A detailed description of the service-related tetrahedron can be found in a document available on a link by reading

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Fig. 13. QR code of delivery/service system description (*Source*: Authors compilation)

the QR code (Fig. 13). The document details the basic definitions and definitions, a detailed description of the tasks and indicators on each side of the tetrahedron.

The authors of the model also made the spatial model of the model, knowing that it would perfect the planar representation. The photos of the spatial model can be found in the study, but due to the visual constraints of the article, they were presented in a two-dimensional form.

The PaTeNt© - QCD model is thus an approach tool that makes information content and relationships touchable. This gives you more support than before:

- exploring and understanding the connections,
- easy communication with goals,
- systems approach thinking.

With the future emergence and spread of 3D presentation techniques, widespread use is expected, as information can be efficiently transmitted through the physical display of relationships and the use of QR codes.

The future logistics envisage a more intensive use of the Internet and virtual space, with the help of which a higher level of communication will be available and collaborative communication and support between man and machine can be realized [39].

With help of the model, the relationships of the company can also be seen visually, thus facilitating easier transparency and indirectly contributing to the development of the entire company processes and to customer relation in the long run.

To detect and know the customer touchpoints is a base for a customer satisfaction [40].

6. CONCLUSIONS

The PaTeNt© - QCD model presented by the authors illustrates the comprehensive QCD framework of supply chains with specific captions. This is very useful for all actors in the supply chain. By visualizing the model, it can effectively and emphatically illustrate the goals of efficient and economical supply chains. This spatial model both in education and in economic life systematizes and illustrates the

- quality elements,
- cost elements and
- delivery elements of supply chains.

The model can also serve as a basis for increasing the economic competitiveness of educators, researchers, and even companies, as well as for supporting the understanding of the given correlation system. As a result of the research, a new QCD organization management tool was created, which is also suitable for the development and coordination of SC processes by exploring the exact correlations.

Furthermore, the model can help to formulate expectations against materials, machines, and instruments. The point is to explore relationships. These possibilities require further research, parallel display with the development of technology.

REFERENCES

[1] B. S. G. Pató, "The 3D job description," *J. Manage. Develop.*, vol. 34, no. 4, pp. 406–20, 2015. https://doi.org/10.1108/JMD-11-2013-0151.

[2] B. S. G. Pató, "Formal options for job descriptions – Theory meets practice," *J. Manage. Develop.*, vol. 36, no. 8, pp. 1008–28, 2017. https://doi.org/10.1108/JMD-01-2016-0019.

[3] B. S. G. Pató, C. Viktória, J. Dóra, and K. Fanni, Ecotourism Competency system in the light of the Canvas model – framework of ECOMODE project. Globalization and Current Challenges in Business. III. International Scientific Conference Proceedings. Georgian Technical University, Faculty of Business Technologies, 2019, pp. 317–21.

[4] B. S. G. Pató and F. Kiss, "The importance of supplier evaluation in short supply chains," *Studia Universitatis Babes-Bolyai, Oeconomica*, vol. 64, no. 2, pp. 1–11, 2019.

[5] B. Telek, *Anamorph*. Budapest: KattArt Kereskedelmi és Szolgáltató Bt, 2012.

[6] J. N. Mazón, J. Lechtenbörger, and J. Trujillo, "A survey on summarizability issues in multidimensional modeling," *Data Knowl. Eng.*, 2009. https://doi.org/10.1016/j.datak.2009.07.010.

[7] R. Stackowiak, J. Rayman, and R. Greenwalk, "Oracle data warehousing and business intelligence solutions," *J. Chem. Inf. Model.*, 2013. https://doi.org/10.1017/CBO9781107415324.004.

[8] B. S. G. Pató, "A model consisted of 5 tetrahedral network, as a scientific research appliance. Social Educational Project of Improving Knowledge in Economics," *J. L'Association 1901 "SEPIKE"*, vol. 4, pp. 63–8, 2014, ISSN: 2196-9531.

[9] M. ten Hompel, H. Büchter, and U. Franzke, "Identifikationssysteme und Automatisierung," in *Identifikationssysteme und Automatisierung*, 2008. https://doi.org/10.1007/978-3-540-75881-5.

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[10] M. Burns, "Deeper learning with QR codes and augmented reality: a scannable solution for your classroom," in *Deeper Learning with QR Codes and Augmented Reality: A Scannable Solution for Your Classroom*, 2017. https://doi.org/10.4135/9781506331751.

[11] M. Monguillot Hernando, C. González Arévalo, M. Guitert Catasús, and C.Z. Mon, "Mobile learning: a collaborative experience using QR codes," *Int. J. Educ. Technol. High Educ.*, vol. 11, pp. 175–91, 2014. https://doi.org/10.7238/rusc.v11i1.1899.

[12] C.-Y. Law and S. So, "QR codes in education," *J. Educ. Technol. Develop. Exchange (JETDE)*, vol. 3, no. 1, 2010, Article 7 https://doi.org/10.18785/jetde.0301.07.

[13] S. Sen, R. A. Rocco, S. Ranganathan, and J. R. Brooks, "Revisiting quick response code technology: corporate perspectives," *Int. J. Mobile Commun.*, vol. 17, no. 6, pp. 703–26, 2019. https://doi.org/10.1504/IJMC.2019.102722.

[14] G. Durak, E. E. Ozkeskin, and M. Ataizi, "QR codes in education and communication," *Turkish Online J. Distance Educ.*, vol. 17, 2016. https://doi.org/10.17718/tojde.89156.

[15] R. M. Monczka, R. B. Handfield, L. C. Giunipero, and J. L. Patterson, "Purchasing & supply chain management," *Successful Project Manage.*, 2009, ISBN: 1285869680.

[16] S. Al Smadi, "Kaizen strategy and the drive for competitiveness: challenges and opportunities," *Compet. Rev. Int. Business J.*, vol. 19, no. 3, pp. 203–11, 2009. https://doi.org/10.1108/10595420910962070.

[17] K. Amasaka, ""New JIT": a new management technology principle at Toyota," *Int. J. Prod. Econ.*, 2002. https://doi.org/10.1016/S0925-5273(02)00313-4.

[18] H. Suh and H. Sohn, "Qualitative analysis of QCD and PPO properties for realization of concurrent engineering," *IFAC Proc. Volumes*, vol. 30, no. 14, pp. 97–101, 1997. https://doi.org/10.1016/S1474-6670(17)42704-2.

[19] A. Thomas, R. Barton, and P. Byard, "Methodology and theory, developing a six sigma maintenance model," *J. Qual. Maintenance Eng.*, vol. 14, no. 3, pp. 262–71, 2008. https://doi.org/10.1108/13552510810899463.

[20] W. Hasrulnizzam Wan Mahmood, N. Mat Tahar, M. Nizam Ab Rahman, Baba, and Deros, "Supply chain enhancement through product and vendor development programme," *J. Model. Manage.*, vol. 6, no. 2, pp. 164–77, 2011. https://doi.org/10.1108/17465661111149566.

[21] T. Machikita and Y. Ueki, "Knowledge transfer channels to Vietnam for process improvement," *Manage. Decis.*, vol. 51, no. 5, pp. 954–72, 2013. https://doi.org/10.1108/MD-08-2012-0600.

[22] M. Ahmed, "Outsourcing relationship management: accounting in the decision mix," *J. Business Strategy*, vol. 39, no. 5, pp. 41–9, 2018. https://doi.org/10.1108/JBS-03-2018-0049.

[23] H. Matsuo, "Implications of the Tohoku earthquake for Toyota's coordination mechanism: Supply chain description of automotive semiconductors," *Int. J. Prod. Econ.*, vol. 161, pp. 217–27, 2015. https://doi.org/10.1016/j.ijpe.2014.07.010.

[24] J.-R. Yu and C.-C. Tsai, "A decision framework for supplier rating and purchase allocation: A case in the semiconductor industry," *Comput. Ind. Eng.*, vol. 55, pp. 634–46, 2008. https://doi.org/10.1016/j.cie.2008.02.004.

[25] P-E. Dossou and P. Mitchell, "Modeling and performance improvement: the Remedy to treat social and environment issues for enterprises in today's difficult economic climate," *LogForum*, vol. 11, no. 1, pp. 29–40, 2015. https://doi.org/10.17270/J.LOG.2015.1.3.

[26] A. Hosono, J. Page, and G. Shimada, Eds. *Workers, Managers, Productivity, Kaizen in Developing Countries*. Palgrave Macmillan, 2020, pp. 1–327. https://doi.org/10.1007/978-981-15-0364-1.

[27] L. Török, "Industry 4.0 from a few aspects, in particular in respect of the decision making of the management," *Int. Rev. Appl. Sci. Eng. IRASE*, vol. 11, no. 2, pp. 140–6, 2020. [Online]. Available: https://akjournals.com/view/journals/1848/11/2/article-p140.xml. Accessed: July 15, 2021.

[28] M. Jayakrishnan, A. K. Mohamad, and M. M. Yusof, "Developing railway supplier selection excellence using business intelligence knowledge management framework," *Int. Rev. Appl. Sci. Eng.*, vol. 12, no. 3, pp. 257–68, 2021. [Online]. Available: https://akjournals.com/view/journals/1848/12/3/article-p257.xml. Accessed: Sep. 24, 2021.

[29] R. Z. Badaoui, M. Boudhar, and M. Dahane, "Preemptive scheduling with transportation delays between machines," *J. Model. Manage.*, vol. 15, no. 3, pp. 829–47, 2020. https://doi.org/10.1108/JM2-11-2018-0187.

[30] R. Suurmond, F. Wynstra, and J. Dul, "Unraveling the dimensions of supplier involvement and their effects on NPD performance: a meta-analysis," *J. Supply Chain Manage.*, 2020. https://doi.org/10.1111/jscm.12221.

[31] S. Oduro, K. M. Nyarku, and R. A. Gbadeyan, "Supplier relationship management and organizational performance of hospitals in an emerging economy context: a comparative study," *J. Model. Manage.*, vol. 15, no. 4, pp. 1451–78, 2020. https://doi.org/10.1108/JM2-03-2019-0072.

[32] N. Komatina, S. Nestić, and A. Aleksić, "Analysis of performance measurement models according to the procurement business process," *Int. J. Ind. Eng. Manage.*, vol. 10, no. 3, pp. 211–8, 2019. https://scidar.kg.ac.rs/handle/123456789/8300.

[33] C. Szász, "Cyber-physical platform development and implementation for industry 4.0," *Int. Rev. Appl. Sci. Eng. IRASE*, vol. 11, no. 1, pp. 66–72, 2020. [Online]. Available: https://akjournals.com/view/journals/1848/11/1/article-p66.xml. Accessed: Sep. 24, 2021.

[34] E. Hofmann and M. Rüsch, "Industry 4.0 and the current status as well as future prospects on logistics," *Comput. Industry*, 2017. https://doi.org/10.1016/j.compind.2017.04.002.

[35] A. Rushton, P. Croucher, and P. Baker, "The handbook of logistics and distribution management," *Project Manage. J.*, 2006. https://doi.org/10.1371/journal.pone.0030504.

[36] A. Vanichchinchai, "Quality management and supply chain management frameworks: a classification," *8th International Conference on Industrial Technology and Management (ICITM)*, Cambridge, United Kingdom, 2019, 22–6 https://doi.org/10.1109/ICITM.2019.8710728.

[37] A. E. Bempong, "The rgole of transportation in logistics chain. TEXILA," *Int. J. Manage.*, 2019. https://doi.org/10.21522/tijmg.2015.05.01.art015.

[38] M. Grazia Speranza, "Trends in transportation and logistics," *Eur. J. Oper. Res.*, 2018. https://doi.org/10.1016/j.ejor.2016.08.032.

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[39] L. Barreto, A. Amaral, and T. Pereira, "Industry 4.0 implications in logistics: an overview," *Proced. Manuf.*, 2017. https://doi.org/10.1016/j.promfg.2017.09.045.

[40] T. Aichner and B. Gruber, "Managing customer touchpoints and customer satisfaction in B2B mass customization: a case study," *Int. J. Ind. Eng. Manage.*, vol. 8, no. 3, pp. 131–40, 2017.

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