ISSN 1330-3651 (Print), ISSN 1848-6339 (Online)
UDC/UDK 006.73:[005.6:672.02]

RESEARCH AND RANKING OF THE FACTORS OF IMPACT ON EFFICIENCY AND EFFECTIVENESS OF THE QUALITY MANAGEMENT SYSTEM CERTIFICATION PROCESS USING THE PRIOR FACTOR RANKING METHOD

Đuro Tunjić, Milan Kljajin, Veljko Kondić

Original scientific paper
This article shows the method of ranking the factors in the study of efficiency and effectiveness of the process of quality management system certification compliant with the requirements of international standard ISO 9001. During the research of efficiency of the quality management systems certification process in enterprises of metal processing industry in Croatia, various impact factors that affect the certification process have been identified. Therefore, the issue arose whether each factor could be treated equally, i.e. whether there are factors that are more important and have a more pronounced effect and greater impact on the certification process. The survey collected the opinions of competent experts in certification institutions, i.e. of external auditors who are directly involved in the certification process, and the representatives of the quality of the companies that have certified the system for at least two years. After the data was collected, ranking of impact factors and analysis of results was conducted.

Keywords: *certification, efficiency, effectiveness, impact factors, prior factor ranking method, quality, quality management system*

Istraživanje i rangiranje utjecajnih faktora na efikasnost i uspješnost procesa certifikacije sustava upravljanja kvalitetom metodom apriornog rangiranja faktora

Izvorni znanstveni članak
U članku se prikazuje primjena metode rangiranja faktora u istraživanju efikasnosti i uspješnosti procesa certifikacije sustava upravljanja kvalitetom usklađenim sa zahtjevima međunarodne norme ISO 9001. Tijekom istraživanja ofikasnosti procesa certifikacije sustava upravljanja kvalitetom u poduzećima metaloprerađivačke djelatnosti u Republici Hrvatskoj, identificirani su različiti utjecajni faktori koji djeluju na sam proces certifikacije. Zbog toga se postavilo pitanje, može li se svaki faktor ravnopravno tretirati, odnosno postoje li faktori koji su važniji i koji imaju izraženije djelovanje i veći utjecaj na sam proces certifikacije? Istraživanjem su prikupljena mišljenja kompetentnih stručnjaka iz certifikacijskih ustanova, odnosno eksternih auditora koji su direktno uključeni u proces certifikacije, te predstavnika za kvalitetu poduzeća koja imaju certificirani sustav u trajanju od najmanje dvije godine. Nakon prikupljenih podataka provedeno je rangiranje utjecajnih faktora i analiza rezultata.

Ključne riječi*: certifikacija, efikasnost, kvaliteta, metoda apriornog rangiranja faktora, sustav upravljanja kvalitetom, uspješnost, utjecajni faktori*

1 Introduction

A large number of certified companies in the world confirm the need for an independent and objective verification of the quality management system and for proving its good organization and structure on the market [5]. Although numerous advantages of certification companies are well known, we can still hear the opposing views. Significant influence of functional and stochastic factors (management, employees, markets, customers, etc.), the complexity of their relationship and the possibility of different effects, make the certification a very demanding process in terms of planning and implementation. The companies that align their quality management systems with the requirements of these standards are expecting "benefit" not only from the implemented system, but also from the certification process. For these reasons, a study has been conducted [1] in relation to the identification and recognition of impact factors on the efficiency of the certification process, as well as their ranking with the goal of finding the factors with the greatest impact levels [2]. In this way, the priorities in the process of improving the certification process have been defined.

2 Research and defining of procedures of ranking the impact factors

In previous research [1, 8] of the efficiency of the process of certification of quality management systems, nine impact factors have been identified:

F_1 – Communication before the audit: term of audit, audit team, audit plan, etc.
F_2 – Auditor's expertise
F_3 – Auditor's competence
F_4 – Professional and correct behaviour of auditors
F_5 – Expertise, knowledge and quality of preparation of employees in the company for audit.
F_6 – The accuracy of determination of non-compliance and areas for improvement by the auditor.
F_7 – Quality of the final meeting: Completeness of information on the results of the audit.
F_8 – Communication after audit conduction: text of certificate, audit report, etc.
F_9 – Quality in conducting surveillance of audits: changing auditors, constant improvement, etc.

For the implementation of ranking the impact factors, 15 external auditors (from different certification companies - EA_i) and 15 quality management representatives (QMR_i) were employed. To identify the dominant factors, according to [2], the method of their a priori ranking was applied. The ranking process and analysis of the impact factors are presented in [9].

3 Ranking of impact factors

3.1 Ranking of factors and realignment of the original rankings

The external auditors EA_i and quality managers (QMR_i) assigned certain ranks to identified impact factors, in terms of their dominance at the very efficiency

of the process of certification of quality management systems (rank 1 most influential, rank 9 least influential). In the evaluating rank, the importance of these factors is shown by using the rating scale (1 ÷ 7): 1 equals the greatest impact, and 7 the lowest. More factors could have the same rank. As the subjects used the possibility of assigning the same rank to various factors, it was necessary to pre-form the ranks. In that case, the factors with the same rank got a new rank, equal to the mean value of the place which factors divided among themselves. In this way, we came from the base table of ranks to the preformed table of ranking the impact factors. Tab. 1 shows the final preformed table of ranks on the example of interviewing EA_i.

In Fig. 1, through comparative diagram Box – Whisker, the impact factors and assigned ranks of preformed ranks EA_i are shown.

Table 1 Preformed table ranking of impact factors

No.	External auditors EA_i	Impact factors j									Correction factor T_i
		F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	
1	1	8,5	6,5	3	4	1	2	6,5	8,5	5	12
	2	7	8,5	1,2	1,2	1,2	1,2	8,5	6	1,2	126
	3	4	5	1,33	1,33	8	6	7	9	1,33	24
	4	1,5	3,5	3,5	1,5	6,5	9	5	8	6,5	18
	5	4,5	6,5	1,33	4,5	1,33	1,33	6,5	8,5	8,5	42
	6	7	8	1,5	6	9	1,5	3,5	3,5	5	12
	7	4	5	1,33	1,33	8	6	7	9	1,33	24
	8	4,5	4,5	2	3	8	1	9	6,5	6,5	12
	9	9	7	1	5,5	5,5	4	2,5	8	2,5	12
	10	9	5,5	1	2,5	2,5	4	5,5	7	8	12
	11	1,25	1,25	1,25	1,25	8	6,5	6,5	9	5	66
	12	9	4	1	2	7,5	5,5	5,5	7,5	3	12
	13	7	6	2,5	2,5	1	4	5	9	8	6
	14	3,5	6,5	1	2	9	6,5	3,5	5	8	12
	15	6	4	1	2,5	2,5	5	7,5	9	7,5	12
2	$\sum_{i=1}^{m} a_{ij}$	87,75	81,75	23,94	41,11	79,03	62,53	89	113,5	77,36	$\sum T_i = 402$
3	$Q_j^{(2)}$	7	6	1	2	5	3	8	9	4	
4	$\sum \Delta_j = \left\lvert \sum a_{ij} - \overline{\sum a_{ij}} \right\rvert$	14,87	14,87	48,94	31,77	6,15	10,35	16,12	40,62	4,48	
5	Δ_j^2	221,11	221,11	2395,12	1009,33	37,82	107,12	259,85	1649,98	20,07	

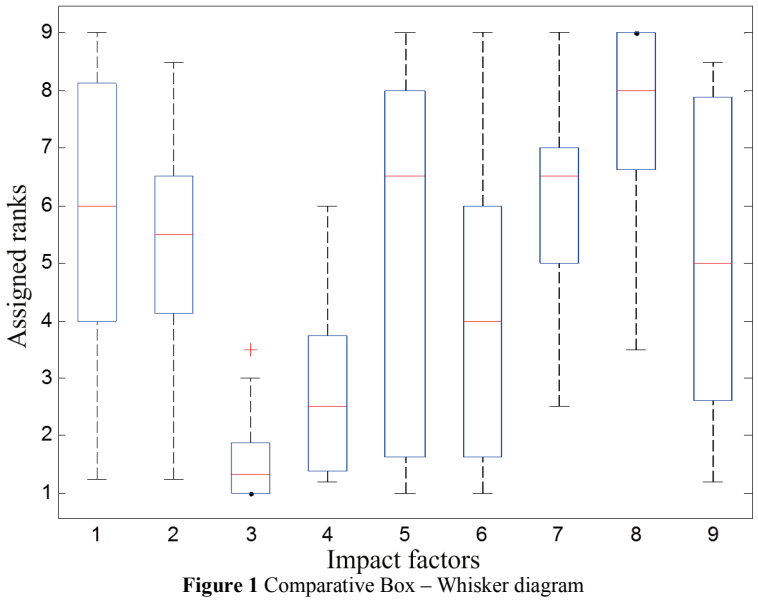

Figure 1 Comparative Box – Whisker diagram

3.2 Checking the adequacy of the original and preformed table

Checking the adequacy of the original and preformed tables was conducted by using the Spearman rank correlation coefficient [4], which can take the values from the closed interval, from −1 to +1:

$$r_s = 1 - \frac{6 \cdot \sum_{j=1}^{k} \left(Q_j^{(1)} - Q_j^{(2)} \right)^2}{k \cdot \left(k^2 - 1 \right)^2}; \quad -1 \le r_s \le 1, \tag{1}$$

where:
k – number of impact factors ($k = 1 \div 9$)

$Q_j^{(1)}$ – ranks assigned to the factors in the initial table according to the total sum of ranks

$Q_j^{(2)}$ – ranks assigned to the factors in the preformed table according to the total sum of ranks.

The statistical value r_s was checked using the t – distribution whose value was calculated according to the formula [6]:

$$t_r = \frac{r_s}{\sqrt{\frac{1-r_s^2}{k-2}}}, \tag{2}$$

where:
k – number of impact factors ($k = 1 \div 9$)
r_s – Spearman rank correlation coefficient.

If the calculated value of t_r exceeds the table values t_t, it is concluded that the correlation coefficient is significant [4, 6].

3.3 Checking the level of consent opinions of respondents

The degree of conformity of opinions of respondents was checked using the Kendall coefficient of consent W which takes the values between 0 and +1 (0 if there is no consent, and +1 if there is full compliance) [4]. Since it came to the repetition of ranks in the actual analysis, the formula for Kendall coefficient consent was added for correction factor for the related ranks T_i [6].

$$W = \frac{12\sum_{j=1}^{k} \Delta j^2}{m^2 \cdot k\left(k^2-1\right) - m\sum_{i=1}^{m} T_i}, \tag{3}$$

where:
k – number of impact factors ($k = 1 \div 9$)
m – number of *EA* and *QMR* ($m = 1 \div 15$)

$\sum_{j=1}^{k} \Delta j^2$ – The sum of squared deviations of the sum of ranks of all external auditors

$\sum_{i=1}^{m} T_i$ – The sum of correction factors related to ranks.

Calculation of the correction factor was performed using the expression [2]:

$$T_i = \sum_{j=1}^{k} (t_t^3 - t_i), \tag{4}$$

where t_i is the number of repetition of the i-th rank in the j-th row.

To check the values of Kendall coefficient of consent W, χ^2 – test with the following indicator was applied [7]:

$$\chi_r^2 = m \cdot (k-1) \cdot W, \tag{5}$$

where the following is required

$$\chi_r^2 > \chi_t^2, \tag{6}$$

where:
m – number of *EA* and *QMR* ($m = 1 \div 15$)
k – number of impact factors ($k = 1 \div 9$)
W – Kendall coefficient of consent.

3.4 Ranking of competence

Respondents (*EA* and *QMR*) differentiated (work experience, vocational training, character, etc.), so it was necessary to carry out the ranking of their competence (Tab. 2).

Table 2 Ranked competences of individual *EA* by experts

No.	Experts h	External auditors EA_i														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	2	15	5	4	1	10	3	13	11	12	9	8	14	6	7
	2	15	13	8	3	4	9	7	6	5	1	2	14	12	11	10
	3	10	11	1	2	3	12	14	9	13	4	7	5	15	6	8
	4	14	10	2	1	3	13	15	8	11	5	7	6	12	4	9
	5	13	14	1	3	4	12	15	10	9	2	5	8	11	6	7
2	$\sum_{h=1}^{5} a_{ih}$	54	63	17	13	15	56	54	46	49	24	30	41	64	33	41
3	$\sum \Delta_i = \left\lvert \sum a_{ih} - \overline{\sum a_{ih}} \right\rvert$	14	23	23	27	25	16	14	6	9	16	10	1	24	7	1
4	Δ_i^2	196	529	529	729	625	256	196	36	81	256	100	1	576	49	1
5	$Z_i = a + b\sum_{h=1}^{5} a_{ih}$ $b = -0,019$ $a = 1,746$	0,72	0,55	1,42	1,50	1,46	0,68	0,72	0,87	0,81	1,29	1,18	0,97	0,53	1,12	0,97

3.5 Testing of the degree of agreement of the respondents

The degree of respondents' conformity of opinions was checked out by using the Kendall coefficient of

consent applying χ^2 – test. As it was concluded in both cases $\chi_r^2 > \chi_t^2$ that the series of ranks were mutually dependent, the hypothesis of the existence of experts consent opinions was accepted.

3.6 Assigning "weight" or "important" to respondents

Respondents were assigned *weight* or their significance. Respondents who had the smallest sum of ranks were assigned the greatest significance, and those with the highest number of ranks the lowest. For other respondents, significance was determined by the expression [2]:

$$Z_i = a + b\sum_{h=1}^{5} a_{ih}. \quad (7)$$

The values of the parameters *a* and *b* were calculated using the system of equations with two unknowns, which were included in the value of the maximum and minimum Z_i, and the value of minimum and maximum rank sum.

3.7 Weighting of preformed ranks of impact factors with importance of *EA* and *QMR*

By weighting of preformed ranks of factors of influence with *importance* (Z_i) of individual *EA*s and *QMR*s, the ranks were assigned with certain *weight* and statistically relevant data was obtained (Tab. 3). Since the Spearman rank correlation coefficient proved the adequacy of the original and preformed tables of the ranks, there is a conclusion that the table of preformed factors of influence weighted with the importance of *EA*s and *QMR*s is adequate to the source table and could be used in future work.

Table 3 Preformed impact factors weighted with the importance of EA_i

No.	External auditors EA_i	Impact factors j								
		F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9
1	1	6,12	4,68	2,16	2,88	0,72	1,44	4,68	6,12	3,60
	2	3,85	4,67	0,66	0,66	0,66	0,66	4,67	3,30	0,66
	3	5,68	7,10	1,89	1,89	11,36	8,52	9,94	12,78	1,89
	4	2,25	5,25	5,25	2,25	9,75	13,5	7,50	12,00	9.75
	5	6,57	9,49	1,94	6,57	1,94	1,94	9,49	12,41	12,41
	6	4,76	5,44	1,02	4,08	6,12	1,02	2,38	2,38	3,40
	7	2,88	3,60	0,96	0,96	5,76	4,32	5,04	6,48	0,96
	8	3,91	3,91	1,74	2,61	6,96	0,87	7,83	5,65	5,65
	9	7,29	5,67	0,81	4,45	4,45	3,24	2,02	6,48	2,02
	10	11,61	7,09	1,29	3,22	3,22	5,16	7,09	9,03	10,32
	11	1,47	1,47	1,47	1,47	9,44	7,67	7,67	10,62	5,90
	12	8,73	3,88	0,97	1,94	7,27	5,33	5,33	7,27	2,91
	13	3,71	3,18	1,32	1,32	0,53	2,12	2,65	4,77	4,24
	14	3,92	7,28	1,12	2,24	10,08	7,28	3,92	5,60	8,96
	15	5,82	3,88	0,97	2,42	2,42	4,85	7,27	8,73	7,27
2	$\sum_{i=1}^{m} a_{ij} Z_i$	78,57	72,71	23,57	38,96	80,68	67,92	87,48	113,62	79,94
	$\sum a_{ij} Z_i = 71{,}49$									
3	$Q_j^{(3)}$	5	4	1	2	7	3	8	9	6
4	$\Delta_j = \left\lvert \sum a_{ij} Z_i - \overline{\sum a_{ij} Z_i} \right\rvert$	7,08	1,22	47,92	32,53	9,19	3,57	15,99	42,13	8,45
5	Δ'^2_j	50,1	1,5	2296	1058	84,5	12,7	255,7	1775	71,4
6	$\overline{a'}_j = \sum_{i=1}^{m} a_{ij} Z_i / \sum_{i=1}^{m} Z_i$	5,31	4,84	1,59	2,63	5,45	4,59	5,91	7,68	5,40
	$\sum_{i=1}^{m} Z_i = 14{,}79$									
7	$M'_j = \frac{\sum_{i=1}^{m} a_{ij} Z_i}{\sum_{i=1}^{m} \sum_{j=1}^{k} a_{ij} Z_i}$	0,122	0,113	0,037	0,060	0,125	0,105	0,136	0,176	0,124
	$\sum_{i=1}^{m} \sum_{j=1}^{k} a_{ij} Z_i = 643{,}45$									

2.8 Checking the level of consent opinions surveyed after the introduction of the factors of significance

The degree of conformity of opinions of respondents was checked by using the Kendall coefficient of consistence for which check of statistical values χ^2 – test was applied. The results confirmed the hypothesis of the existence of consent opinions surveyed by *EA* and *QMR*s.

2.9 Determining the degree of each impact factor

The degree of influence of each factor on certain occurrence was determined by using the coefficient of significance of impact factors [5]:

$$M'_j = \frac{\sum_{i=1}^{m} a_{ij} Z_i}{\sum_{i=1}^{m} \sum_{j=1}^{k} a_{ij} Z_i}. \quad (8)$$

Fig. 2 shows an a priori diagram of the factors ranks impact on the efficiency of the certification of quality management systems process according to the ranking of the *EA*, and Fig. 3 of the *QMR*s.

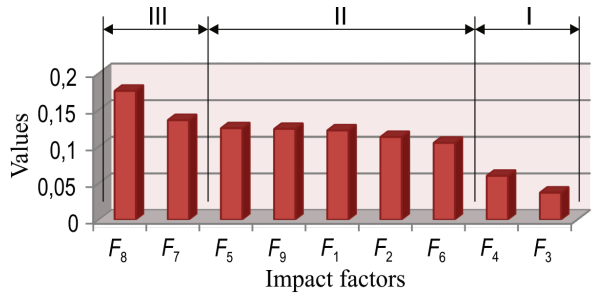

Figure 2 A priori diagram of the factors ranks impact on the efficiency of the process of certification audit of QMS (Quality Management System), according to *EA* opinion

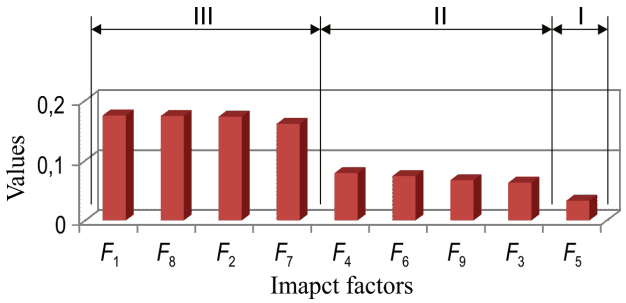

Figure 3 A priori diagram of the factors ranks impact on the efficiency of the process of certification audit of SUK, according to QMR opinion

The factors that affect the efficiency of the certification audit of quality management system can be classified into three groups (Tab. 4).

By comparing these two diagrams, it is evident that the *QMR*s emphasize the importance and role of the organization itself, while the EA gives the highest importance to the place and role of external auditor himself. However, there is a match between *EA* and *QMR*, except for the impact factors F_5, Fig. 4. In the procedures of improving, more attention should be given to the most important factors (F_3 expertise of auditors, F_4 - professional and correct behaviour of auditors and F_5 - a company employee) but of course, other factors should not be neglected.

Table 4 Factors that affect the efficiency of the certification

Mark	Importance of factor	EA_i	QMR_i
I	The most influential factors	F_3, F_4	F_5
II	Less influential	F_1, F_2, F_5, F_6, F_9	F_3, F_4, F_6, F_9
III	The least influential factors	F_7, F_8	F_1, F_2, F_7, F_8

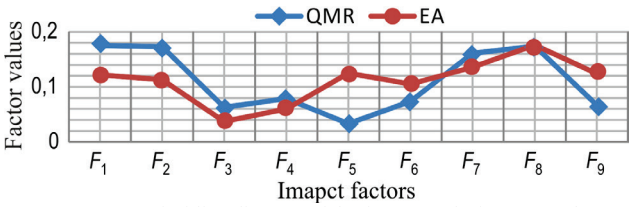

Figure 4 A priori line diagram of the factors ranks impact on the efficiency of the process of certification audit of QMS, according to the *EA* and *QMR* opinion

4 Conclusions

From the obtained results, the difference in approach by *QMR* and *EA* is visible. *QMR*s consider expertise, knowledge and quality of preparation of the firm's staff for audit as the most important factors, while EA puts the expertise and professionalism of auditors in the first place. These are simply two views and two groups with different interests, and the situation in which both sides are right. EA sees its job of auditing, and from its aspect, expertise and knowledge of the auditor himself are the most important. They review the functioning of the system and do not think that preparation of employees can significantly affect the results of the audit. On the other hand, *QMR*s with their point of view and everyday situations that they have, see just the active involvement of all employees in the preparation for audit as the most important factor. Further research would likely come to the conclusion that this assessment basically relates to things on a daily basis active involvement in the implementation of the system. *QMR*s themselves are also aware that it is not possible to prepare for the audit in only a few days, but that the daily use of the system requirement is necessary.

On average, three factors (F_3, F_4 and F_5) are separated as the most influential. Particularly interesting is the factor F_5, because *QMR* rated it as the most influential, and significant impact is assigned by *EA* too. Since this factor relates to the expertise, knowledge and proper preparation of employees, in this way the need for the action to raise awareness about the quality of employees in enterprises has been proven yet another time. It is necessary to implement the education of a wider group of employees, not just those who are active in building up and auditing systems. Without education and raising of awareness about the importance of quality, it will be difficult to raise the system to a higher level and to direct it towards business excellence.

5 References

[1] Tunjić, Đ. Učinkovitost certifikacije sustava upravljanja kvalitetom prema normi ISO 9001 u metaloprerađivačkoj industriji, Doktorska disertacija, SFSB, Sveučilište Josipa Jurja Strossmayera u Osijeku, 2013. (In Croatian)

[2] Kondić, Ž. Prilagodba metodologije 6-σ u proizvodnim organizacijama, Doktorska disertacija, FSB, Zagreb, 2008. (In Croatian)

[3] Hodžić, E. Kvalitet kao temeljni oslonac konkurentskih prednosti Elektroprivrede Bosne i Hercegovine, Magistarski rad, Ekonomski fakultet u Sarajevu, Sarajevo, 2005. (In Bosnian)

[4] Horvat, J. Statistika pomoću SPSS/PC+, Sveučilište Josipa Jurja Strossmayera u Osijeku, Ekonomski fakultet Osijek, Osijek, 1995. (In Croatian)

[5] Tunjić, Đ.; Maglić, L.; Kondić, Ž.; Kljajin, M. Utjecaj certifikacije sustava upravljanja kvalitetom na konkurentnost u hrvatskom gospodarstvu. // KVALITET 2013, Conference Proceedings, Neum, B&H, 2013. (In Croatian)

[6] Serdar, V.; Šošić, I. Uvod u statistiku, Školska knjiga, Zagreb, 1990.

[7] Pavlić, I. Statistička teorija i primjena, Tehnička knjiga, Zagreb, 1988.

[8] Tunjić, Đ.; Maglić, L.; Kondić, Ž.; Kljajin, M.; Kondić, V. Ranking of factors on efficiency and effectiveness of the process quality management system certification according to the external auditors' evaluation. // Tehnicki vjesnik-Technical Gazette. 50, 6(2013). pp. 1051-1055.

Authors' addresses

Đuro Tunjić, Ph.D.
TÜV Croatia d.o.o., TÜV NORD Group
Savska 41, 10000 Zagreb, Croatia
E-mail: dtunjic@tuv-croatia.hr

Milan Kljajin, Ph.D., full professor
J. J. Strossmayer University of Osijek,
Mechanical Engineering Faculty in Slavonski Brod,
Trg Ivane Brlić-Mažuranić 2,
35000 Slavonski Brod, Croatia
E-mail: mkljajin@sfsb.hr

Veljko Kondić, Mag. Eng. ME
Polytechnic of Varaždin,
J. Križanića 33,
42000 Varaždin, Croatia