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Exploring leadership styles for innovation: an exploratory factor analysis

Warit Wipulanusat, Kriengsak Panuwatwanich, Rodney A. Stewart

ABSTRACT

Leadership plays a vital role in building the process, structures, and climate for an organisation to become innovative and to motivate team expectations toward innovations. This study explores the leadership styles that engineers regard as significant for innovation in the public sector. Exploratory factor analysis (EFA) was conducted to identify the principal leadership styles influencing innovation in the Australian Public Service (APS), using survey data extracted from the 2014 APS employee census comprising 3 125 engineering professionals in Commonwealth of Australia departments. EFA returned a two-factor structure explaining 77.6% of the variance of the leadership for innovation construct. In this study, the results from the EFA provided a clear estimation of the factor structure of the measures for leadership for innovation. From the results, the two factors extracted were transformational leadership and consideration leadership. In transformational leadership, a leader values organisational objectives, inspires subordinates to perform, and motivates followers beyond expected levels of work standards. Consideration leadership refers to the degree to which a leader shows concern and expressions of support for subordinates, takes care of their welfare, treats members as equals, and displays warmth and approachability. These findings highlight the role of leadership as the most critical predictor when considering the degree to which subordinates strive for creativity and innovation. Both transformational and consideration leadership styles are recommended to be incorporated into management training and development programs. This study also recommends that Commonwealth departments recruit supervisors who have both of these leadership styles before implementing innovative projects.

KEY WORDS

leadership, innovation, engineer, public sector, exploratory factor analysis

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Introduction

In Australia, total government expenditure as a proportion of GDP is around 34%. Therefore, the public sector generates a sizable proportion of economic output and substantially more than the share of manufacturing in most countries (Arundel & Huber, 2013). Innovation in the public sector is of high policy interest as it has the potential to improve the efficiency and quality of government services (Moore & Hartley, 2008). Innovation in a public sector context is defined as the search for creative or novel resolutions to problems and demands, including new services, new organisational structures and improved process (Currie et al., 2008).

Innovations have a propensity to be the result of strategic responses or projects through which organi-

sations operate effectively, and to which leadership of organisations must commit key and strategic resources to support innovations in order for these to succeed (Oke et al., 2009). In the achievement of organisational innovation, leadership plays a vital role in building the process, structures, and climate for an organisation to become innovative and to motivate team expectations toward innovations (Chan et al., 2014). As such, the significance of leadership style in creating an innovative organisation is not in question. Leadership style arises from a behavioural review of the approach in which leaders perform their functions (Liu et al., 2003). The research question addressed in this article is: What leadership styles support innovation in the public sector as perceived by engineering professionals?

In this study, the dimensionality of leadership for innovation was analysed using an exploratory factor analysis (EFA). EFA was employed to analyse the inter-relationship between variables and to explore the factor structure of their measure. EFA can be used to identify appropriate variables and analyse the relationships among large numbers of variables in the most general form, explaining them in terms of their common underlying dimensions (Hair et al., 2010).

The paper begins with a literature review, then describes the methodology employed, followed by the results. The paper then discusses the findings and ends with key conclusions from the study.

1. Literature review

The aim of this section is to bring together some key contributions from the literature on leadership styles in the public sector. This section provides a comprehensive and structured perspective on how leadership style in the public sector is theoretically understood. Relevant research and empirical studies are critically reviewed to provide a theoretical foundation to the research question.

According to Bass and Bass (2009), leadership refers to an interaction between two or more members of a group that often involves a structuring or restructuring of the situation and of the perceptions and expectations of the members so as to achieve the common goals. Leadership is one of the most critical predictors when considering the degree to which subordinates strive for creativity and innovation (Amabile et al., 2004; Panuwatwanich et al., 2008). For example, Kim and Lee (2009) investigated management capacity in the innovation process in the Korean public sector and highlighted the importance of innovative leadership on the adoption and implementation of innovations. The willingness of leaders to take risks on novel initiatives and adopt fresh perspectives is the main factor in the success of innovation implementation (Orazi et al., 2013).

The current literature on leadership emphasises different characteristics that can facilitate innovation. One of leadership styles that is considered appropriate to enhance innovation in changing environment is transformational leadership. For example, Shin and Zhou (2003) indicated there was a positive relationship between transformational leadership and employee creativity. In contrast, transactional leadership is characterised by individual gain and the exchange of rewards for effort, and there is a well-defined hierarchy. However, compared to the transformational style of leadership, a study by Pastor and Mayo (2006) found that transactional leadership had less impact on employee learning and creativity. Additionally, literature about governance, collaboration and networks in the public sector has highlighted consideration leadership style which focuses on support and concern for employees. Thus, two leadership styles have been identified in terms of their relevance to innovation and public leadership: transformational leadership and consideration leadership.

1.1. Transformational leadership

Since Burns (1978) introduced the concept of transformational leadership, many scholars and practitioners have paid increasing attention to studying the effectiveness of this leadership style (Bass & Riggio, 2006; Wright & Pandey, 2009; Yukl, 2006). Transformational leadership has generally been considered more effective than other leadership styles in facilitating employee creativity and organisational innovation (García-Morales et al., 2012; Shin & Zhou, 2003). Transformational leaders are those who inspire subordinates to perform and recognise organisational objectives and goals and have the capability to motivate followers beyond expected levels of work standards. Consequently, subordinates feel engaged and personally rewarded through their job, and work outcomes, such as job satisfaction and extra effort, are increased (Bass & Riggio, 2006). In contrast to transactional leadership, transformational leaders motivate behaviour by changing the basic values, beliefs, attitudes and assumptions of subordinates. To direct and inspire individual effort, these leaders transform

their subordinates by raising their awareness of the importance of organisational outcomes, which, in turn, activates their higher-order needs and induces them to transcend their own self-interests for the benefit of the organisation (Wright & Pandey, 2009).

In the public sector, transformational leadership has a mission-driven form which boosts follower receptivity to reform and innovation (Gabris et al., 2001). Emphasis on the mission of an organisation makes transformational leadership particularly effective in the public sector given the service and community-oriented characteristics of their responsibilities (Wright & Pandey, 2009). Furthermore, Wright et al. (2012), in their national study of city managers and department heads, found that transformational leadership was associated with a developmental culture characterised by innovation, entrepreneurial risk-taking, and growth. The transformational leader encourages new ideas and practices by supporting subordinates with sufficient autonomy and discretion for innovation to emerge (Gumusluoglu & Ilsev, 2009). Similarly, transformational leadership has been shown to increase employee empowerment even in public sectors associated with high levels of bureaucracy and a strict hierarchy (Park & Rainey, 2008).

1.2. Consideration leadership

In addition to transformational leadership, the characteristics of consideration leadership also play a vital role in innovation outcomes (Yukl, 2006). Consideration is one of the two leader behavioural dimensions identified by the research cadre at the Ohio State University in the late 1940s (Lee & Kwak, 2014). More than a thousand leader behaviours were examined and summarised into two groups: consideration and initiating structure (Halpin, 1957). Consideration is the degree to which a leader shows concern and expressions of support for subordinates, looks out for their welfare, treats members as equal, and displays warmth and approachability (Bass & Bass, 2009). Initiating structure is the degree to which a leader clarifies the task responsibilities of the leader and of subordinates, determines standards of performance, and establishes well-defined patterns and channels of communication. Consideration leader behaviours provide a work environment of emotional support, friendliness, warmth, and trust for followers. Some exemplary behaviours are helping followers with personal problems, being approachable, advising employees regarding personal problems, and expressing appreciation and support (Lee & Kwak, 2014).

Consideration leadership promotes empowerment of individual subordinates, and this relates to innovative behaviour and effectiveness. According to Frischer (1993), the empowering manager perceives the influence of individuals and work groups and thus, creates an innovative climate where subordinates achieve better results in their innovative initiatives. Consideration leadership also manages the negative issues related to diversity; that is the potential "us – them" differentiations and subsequent breakdown in relationships, because it restricts subgroup classification processes and smoothes relational processes, both of which play important roles in the effective functioning of diverse groups (Mannix & Neale, 2005). The staff always expects the leadership to be a human being and considerate but also to be genuine.

2. Research methods

Data released by the Australian Public Service Commission (APSC) from the 2014 APS employee census was used for this study. The target population for this study was the engineering profession in Commonwealth departments which was classified as the Engineering and Technical Family in the APSC Job Family Model. Of all respondents, 3 570 respondents reported the type of work as Engineering and Technical Family. Cases, where an entire section was left blank, were eliminated from the sample as nonresponsive. As a result, data cleaning further reduced the sample size to 3 125. The instrument used in this paper was adapted by the researchers after an extensive review of all the questions in the 2014 APS employee census. The 11 survey questions were selected and grouped according to leadership theory and were used to measure leadership styles that enable innovation. Building on the ideas of innovation, the respondents were given the following definition of innovation: 'to find new ways of doing work and solving problems'.

The quantitative analysis commenced with multivariate statistics to analyse the data using the Statistical Package for the Social Sciences (SPSS) version 22 software. The data analysis started with univariate data screening which included the examination of missing data, item normality, and the detection of possible outliers. Descriptive analysis was employed to gain a feel for the data and to consider whether the

obtained data was suitable for multivariate analysis and could be used as one data set. To confirm the homogeneity of responses, analysis of variance (ANOVA) was conducted to determine whether the data could be used to represent a single dataset.

The validity of the measurement scale was evaluated using exploratory factor analysis (EFA). EFA was conducted to condense the large number of items into a smaller, more controllable set of dimensions (Hair et al., 2010). In this paper, EFA was applied to determine the adequate number of latent factor structures and to identify the number of factors underlying, conceptually and statistically, the set of items in each construct. In general, the EFA technique identifies appropriate variables and analyses the relationships among large numbers of variables in the most general form, explaining them in terms of their common underlying dimensions (Hair et al., 2010). The results from the EFA provided a clear estimation of the factor structure of variables.

3. Descriptive analysis

3.1. Demographic profiles

Understanding the characteristics of the collected sample is important to determine whether the sample could sufficiently represent the population of interest. This is necessary to establish the validity of the conclusions drawn for the whole population. The demographic factors undertaken in this study were gender, age group, classification level, the length of service, qualification, agency cluster and agency size.

Analyses of the demographic data suggested that the sample for this research was valid and adequately representative of the whole population. The sample population represented a gender mix of 14% female and 86% male predominantly aged between 45 and 59 (49%) who had total length of service for more than 5 years (73%); 68% worked in an operational role (APS 1–6) and were well educated, with 78% holding tertiary qualifications (Bachelor or higher); 86% worked in operational agencies, and 91% worked in large agencies (>1 000 employees). The distribution of these variables approximated the distribution of the population from which they were drawn.

3.2. Data screening

The data screening started with the univariate data screening which included the examination of missing data, item normality, and the detection of possible outliers. This was conducted to ensure there would be no corrupted data which could affect the accuracy of the estimation in the subsequent analysis (Tabachnick & Fidell, 2007).

Missing data is one of the most common problems in data analysis. The result of a Missing Completely at Random (MCAR) test yielded non-significant Chi-square statistics (χ^2= 167.384, *df* = 180, Sig. = 0.741) demonstrating a non-significant difference between the observed missing data pattern and a random pattern, and highlighting that the missing data were randomly distributed. As the percentage of missing data consisted of less than 5% of the total responses and the pattern was completely random, then any imputation method could be applied (Hair et al., 2010; Tabachnick & Fidell, 2007). Therefore, the missing data were imputed by the Expectation Maximisation approach. This technique iteratively goes through the data while still preserving its covariance structure (Ghomrawi et al., 2011).

The normality of the data was investigated by calculating the statistics of skewness and kurtosis and comparing them with the 'rule of thumb values' of ±2.58 (Hair et al., 2010). Skewness is a measure of symmetry which affects tests of means, whereas kurtosis is a measure of how the peakedness of a distribution impacts tests of variances and covariances. The skewness values ranged from -1.25 to -0.64, and were thus inside the threshold, which indicated that the respondents answered these questions quite similarly. The kurtosis values ranged from -0.07 to +2.20, again falling within the recommendation range (Table 1). This is consistent with expectations that the effect of skewness and kurtosis disappears with samples of 200 or more (Tabachnick & Fidell, 2007).

Outliers refer to scores that have a substantial difference between actual and predicted values of the observations (Hair et al., 2010). Cases with responses greater than three standard deviations beyond the mean may be determined outliers, which can be calculated from an absolute value of z-scores (|z|) greater than 3.29 (Kline, 2015; Tabachnick & Fidell, 2007). Four variables containing cases with an absolute value of z-scores (|z|) greater than 3.29 had outliers from 0.6 to 2.3 percent. Based on Field's suggestions (Field, 2013), the number of such outliers should be less than one percent. Therefore, the number of these outliers was moderate compared with a standard level.

To confirm that the outliers did not bias the means, the difference of the mean and the '5% trimmed

Tab. 1. Covariance structure analysis: descriptive statistics

Variable	Mean	SD	Skewness	Kurtosis
A1: Motivate people to understand the strategic direction of the APS	3.51	1.04	-0.64	-0.07
A2: Encourage people to find new ways of doing work	3.57	1.01	-0.67	0.14
A3: Encourages people to learn from work and develop new skills	3.57	1.03	-0.71	0.12
A4: Achieve results by building agency capability and responsiveness	3.78	0.91	-0.91	0.96
A5: Cultivate productive working relationships	3.71	1.00	-0.86	0.43
A6: My supervisor is open to new ideas	3.85	0.88	-0.97	1.26
A7: My supervisor communicates effectively regarding the risks	3.72	0.99	-0.83	0.43
A8: My supervisor accepts people from diverse backgrounds	4.09	0.72	-0.79	1.69
A9: Work effectively with people from diverse backgrounds	3.96	0.77	-0.85	1.75
A10: My supervisor is committed to workplace safety	4.12	0.69	-0.85	2.18
A11: My supervisor treats people with respect	4.02	0.87	-1.25	2.20

Source: authors' calculation using SPSS program.

mean' of each variable was calculated to determine whether the outliers may have distorted the data. The 5% trimmed mean refers to a mean calculated from a set of observations where the five percent of the scores in the upper and lower bounds are removed.

Tab. 2. Outliers analysis

Question	Case with |z|>3.29	Mean	5% Trimmed Mean	Δ Mean
A8	0.6%	4.09	4.13	0.04
A9	1.2%	3.96	4.00	0.04
A10	0.6%	4.12	4.16	0.04
A11	2.3%	4.03	4.11	0.08

Source: authors' calculation using SPSS program.

The outliers may cause a problem to the dataset if the difference between the mean and the '5% trimmed mean' is greater than 0.20 (Pallant, 2013). The extent of the difference of every variable was relatively small, ranging from 0.04 to 0.08 (Table 2). Thus, these results confirmed that the detected outliers did not distort the data set and therefore, all 3 125 cases were retained for further analysis.

3.3. Preliminary findings

The descriptive analysis was presented based on the values of mean and standard deviation. The mean value is the central tendency measurement, used to describe the average opinion of the respondents and to obtain an overall picture of the respondents' perceptions regarding each variable. This section evaluates and interprets the mean values of all 11 variables (Table 1). The respondents stated their agreement that their supervisors had strong innovation conducive behaviours, indicated by the mean value of the 'leadership for innovation' being higher than the medium level of 3.00, ranging from 3.51 to 4.12. Employees were positive regarding their supervisors' support for innovation (A2; 3.57) and openness to new ideas (A6; 3.85). Supervisory capabilities were particularly appreciated in the areas included in the APS Integrated Leadership System (Podger et al., 2004), such as motivating people (A1; 3.51), developing people (A3; 3.57), and achieving results (A4; 3.80). Compared to the other variables, most subordinates had a more positive view of their supervisors' characteristics in terms of accepting members from diverse backgrounds (A8; 4.09) and working effectively with them (A9; 3.96). Subordinates were most likely to be satisfied with their supervisors for their expression of respect for subordinates (A10; 4.12) and their commitment to workplace safety (A11; 4.03).

3.4. ANOVA test of single sample

After screening the data set, one-way analysis of variance (ANOVA) was undertaken to determine whether significant differences existed between the opinions evident in the responses of managers and subordinates in APS. Subordinates are classified as employees who perform at levels between APS 1 to APS 6, the lowest strands of employment classification, where staff are accorded little or no managerial responsibilities, whereas Executive Level (EL) staff represent middle management including sectional heads within departments.

ANOVA was conducted to compare the variance between the mean score of these two groups. ANOVA is conducted to calculate the ratio of systematic vari-

ance to unsystematic variance (*F*-ratio) in an experimental study by comparing the variance between the mean score of these two groups (Field, 2013). If the amount of the ANOVA's *F* statistic is significant, it indicates that the means for managerial and subordinate staff are not statistically equal. However, as recommended by Panuwatwanich (2008), the value of the mean difference should also be considered. The difference is considered significant if the difference is greater than 1.00 representing one category difference in opinion. Moreover, the effect size of the difference (η^2) needs to be considered. The effect size can be calculated by dividing the sum of squares between-group by the total sum of squares. If the effect size is small (i.e. less than 0.14), the significant difference between the mean, as identified by *F*-ratio may not be of practical importance (Pallant, 2013).

Tab. 3. ANOVA results for subordinate and manager

Variable	*F*	Sig.	Mean		Δ Mean	Effect Size
			Subordinate	Manager		
A8	12.707	0.000	4.06	4.16	0.10	0.004
A9	5.931	0.015	3.94	4.01	0.07	0.002

Source: authors' calculation using SPSS program.

The results of ANOVA were based on opinions of the engineering professionals from the operational level (n = 2203) and managerial level (n = 912). As shown in Table 3, the results obtained in the ANOVA analysis revealed a statistically significant difference of 2 variables. However, there was neither a large mean difference nor a large effect size. As a result, all 11 variables were retained in the data set for further analysis.

4. Exploratory Factor Analysis

Two basic assumptions of factor analysis, multivariate normality and sampling adequacy, should be tested before extracting the factors to confirm the suitability of the collected data for the EFA (Lattin et al., 2003). By using SPSS, Bartlett's test of sphericity can determine the multivariate normality of the variables. In addition, this test is used to validate the hypothesis that the correlation matrix is an identity matrix (i.e., a spherical set of multivariate data), (Lattin et al., 2003). The Kaiser-Meyer-Olkin (KMO) test evaluates sampling adequacy regarding whether the distribution of values is sufficient for conducting factor analysis (George & Mallery, 2016). According to Tabachnick and Fidell (2007), data is factorable when the KMO is above the minimum acceptable level of 0.60. KMO values over 0.8 indicate that included variables are 'meritoriously' predicted without error by other variables. In this study, the KMO value of the variables was 0.943, which indicated sampling adequacy and that the distribution of the values in the matrix was appropriate to conduct factor analysis (George & Mallery, 2016). The value obtained by Bartlett's test of sphericity, χ^2 (55) was 31673.31 which was highly significant at $p < 0.001$ level, indicating that the data were approximately multivariate normal (George & Mallery, 2016; Lattin et al., 2003). The result also confirmed that the correlation matrix could not be construed as an identity matrix (Lattin et al., 2003), and therefore, was sufficient to test the factor analysis.

To develop an appropriate solution that shows an adequate number of factors best representing the interrelations among the set of variables, the EFA conducted two essential steps: factor extraction; and factor rotation and explanation (Pallant, 2013; Tabachnick & Fidell, 2007). Factor extraction reveals factors based on the adequacy of the number of factors, while factor rotation improves the explanation of a given factor solution (Field, 2013; Tabachnick & Fidell, 2007). Principal component analysis (PCA) was chosen as a data extraction method because its primary objective is to summarise and reduce data as well as define the factors needed to represent the structure of a variable (Hair et al., 2010). The goal of PCA is to extract the maximum variance from the data set with each component.

Four criteria are used to achieve the number of factors that best describe the underlying relationship among variables, namely: 1) latent root criterion; 2) Catell's scree test; 3) percentage of variance criterion; and 4) a priori criterion (Hair et al., 2010). The latent root criterion recommends that factors be extracted based on total variance, using eigenvalue set to unity (value = 1.0). The Catell's scree test employs a graphical plot of the eigenvalue of the factor in their order of extraction in which a sudden change of slope in the graph indicates the maximum number of factors to

be extracted and determines the number of factors to retain (Pallant, 2013). To determine a sudden change of slope, researchers draw a horizontal line and a vertical line starting from each end of the curve. The percentage of variance criterion is used to confirm practical significance for the extracted factors through which the particular amount of variance is explained (Tabachnick & Fidell, 2007). A priori criterion is a simple and reasonable criterion in which the number of factors is known prior to conducting the factor analysis. As well as considering these four criteria, the conceptual foundation should also be integrated with empirical evidence when considering the appropriate factors to extract (Hair et al., 2010). Once the factors are extracted, factor loadings are used to determine the degree to which the variables load onto these factors (Field, 2013).

After the factor extraction, factor rotation is conducted to present the pattern of loadings in a format that is easy to understand. Varimax rotation, which can load variables to factors clearly, was conducted to maximise the variance of factor loadings and minimise the number of variables that had high loadings on each other (Pallant, 2013; Tabachnick & Fidell, 2007). The resultant factors are presented in a rotated component matrix, and are justified by factor loadings that indicate the degree of correlation between each variable and the factor. A factor loading of 0.50 is considered to be practically significant and therefore has been used as the cut-off level in this study.

Initially, there was a total of 11 variables, chosen to operationally define the Leadership for Innovation (LFI). The EFA was conducted to form a smaller manageable dimension. The two factors for the LFI construct were produced using a priori criterion because the construct was clearly conceptualised to have two distinct components: transformational leadership and consideration leadership.

A geometrical approach can be adopted by the EFA in which factors can be visualised in a coordinate system. The factors are represented by the axes of a graph in which variables are plotted (Field, 2013). When the coordinates of variables are in close proximity to each graph, this represents the strength relationship between that variable and each factor. This scenario indicates that the variable is related to that particular factor. The coordinate of a variable along the factor axis, which acts as a reference frame, represents a factor loading. The variables were plotted as a function of the factors, as shown in Fig. 1. Six variables (A1, A2, A3, …, A6) have high factor loadings (i.e., a strong relationship) with factor 1 (transformational leadership: horizontal axis) but have a low correlation with factor 2 (consideration leadership: vertical axis). In contrast, four variables have strong relationships with consideration leadership but low correlation with transformational leadership.

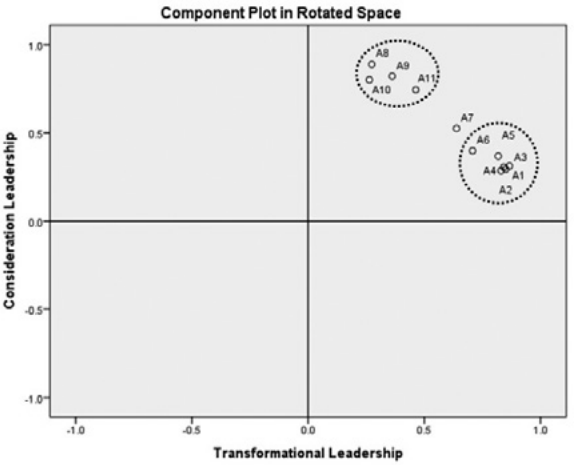

Fig. 1. Geometrical representation of factor analysis of LFI
Source: authors' calculation using SPSS program.

The Cattell's scree test employs a graphical plot of the eigenvalue of the factor in their order of extraction in which a sudden change of slope in the graph indicates the maximum number of factors to be extracted and determines the number of factors to retain (Pallant, 2013). A horizontal line and a vertical line beginning at each end of the curve were drawn to ascertain if there was a sudden change of slope. Examination of the scree plot indicated that a sudden change of slope occurred after the second component (Fig. 2). The Cattell's scree test also identified these two factors, which accounted for 77.6 percent of the total variance.

Prior to extracting factors, communality estimates must be generated. Communality is the proportion of observed variance accounted for by the common factors. These values represent the total amount of variance for an item explained by the extracted factors. The communality is denoted by h^2 and is the summation of the squared factor loadings of a variable across factor (Tabachnick & Fidell, 2007). Generally, a variable will be excluded from the analysis if it has low communalities (less than 0.20), which means that 80% is unique variance. This is because the objective of factor analysis is to describe the variance through the common factors (Child, 2006).

The formula for deriving the communalities is (Cattell, 1973):

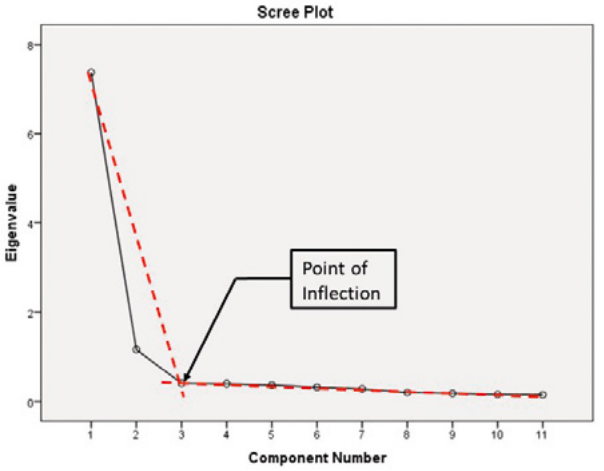

Fig. 2. Scree plot of principal component factoring

Source: authors' calculation using SPSS program.

$$h_j^2 = a_{j1}^2 + a_{j2}^2 \ldots \cdots + a_{jn}^2 \quad (1)$$

where: *a* equals the loadings for *j* variables.

Using the factor loadings in Table 4, the communality of variable A1 was calculated using the aforementioned formula:

$$h_{A1}^2 = 0.866^2 + 0.312^2 = 0.848. \quad (2)$$

Table 4 represents the factor loadings and the contribution of each variable to the factors. In this case, A1 has the highest contribution to Factor 1. The calculated communality indicates that based on the knowledge of the two factors 84.8% of variable A1 can be predicted. If a variable has a high communality, the set of factors can be said to explain much of the variance of a variable (Kline, 2015).

The loading patterns of all 11 variables revealed that variable A7 was cross loaded two constructs, and was thus eliminated. Therefore, 10 variables with factor loadings ranging from 0.708 to 0.889 were retained. The variables with high loadings on component 1 centred on transformational leadership, whereas the variables with high loadings on component 2 were concerned primarily with consideration leadership. Based on these 10 variables, Cronbach's alpha coefficient was recalculated yielding a value of 0.945, indicating the modified measurement scale still had very good internal consistency.

Overdetermination of a factor is the extent to which each factor is clearly shown to have an adequate number of variables and the degree to which each factor is sufficiently defined by a set of indicators. Highly overdetermined factors are determined when there are high factor loadings on at least three to four variables, these variables have moderate to high communalities (i.e., between 0.40 and 0.70 or higher), and exhibit good simple structure (Fabrigar et al., 1999; MacCallum et al., 1999). Both factors had four or more items per factor, the factor loadings ranged from 0.708 to 0.889 and communalities ranged from 0.660 to 0.866, indicating relatively strong data.

Tab. 4. EFA of leadership for innovation

Variable	Rotated Component		H^2
	1	2	
A1	0.866	0.312	0.848
A2	0.851	0.294	0.811
A3	0.842	0.306	0.803
A4	0.830	0.286	0.771
A5	0.818	0.369	0.806
A6	0.708	0.399	0.660
A7	0.639	0.526	0.685
A8	0.274	0.889	0.866
A9	0.362	0.822	0.807
A10	0.264	0.801	0.711
A11	0.463	0.745	0.769

Source: authors' calculation using SPSS program.

Tab. 5. Factors of leadership for innovation

Factor	Description	% of the variance
Transformational leadership	motivate people, encourage innovation, develop people, achieve results, cultivate relationships, and open to new ideas	67.1
Consideration leadership	accept and work with diverse people, commit to workplace safety, and treats people with respect	10.5

Source: authors' calculation using SPSS program.

Table 5 shows the two leadership factors from EFA. It shows there is one very strong factor, which explains 67.1 per cent of the variance and involves a group of variables that relate to transformation leadership styles such as commitment, encouragement, stimulation, intelligence and achievement. This has been labelled 'transformational leadership'. The second innovation leadership type relates to the 'consideration leadership' style which concerns a view to show trust in followers and to provide a safe work

environment, accept diversity, and treat employees respectfully. These second factors explain only small proportions of the variance of 10.5 per cent.

Conclusions

In this paper, a comprehensive investigation of leadership for innovation in the public sector is presented. Perspectives on leadership for innovation were identified by EFA using principal component analysis (PCA) with varimax rotation to assess the dimensionality of the leadership for innovation construct. To interpret the meaning of a factor, the salient variables in each factor were identified and used as the indicators for explanation. The salient variables identified for each extracted factor were higher than 0.5, indicating a substantial degree of contribution of each variable to its extracted factor.

Two factors were extracted from the 11 variables which were selected and grouped according to leadership theory. From the results, one variable was cross loaded between two constructs, and was thus eliminated. Thus, 10 variables with factor loadings ranging from 0.708 to 0.889 were retained. The findings from this study confirm that the accuracy of factor solutions of the EFA model is dependent on the magnitudes of communalities and factor loadings as well as the degree of overdetermination. This finding supports results from other studies emphasising the importance of high factor loadings, high communalities, and overdetermination in achieving quality factor solutions (Hogarty et al., 2005; MacCallum et al., 1999).

The two factors extracted as characterising leadership for innovation were transformational leadership and consideration leadership. This paper shows that transformational leadership and consideration leadership are two predominant styles of leadership within the realm of innovation in the public sector. This result was indicated by these two factors explained for 77.6 percent of the total variance. Based on the views of respondents in the survey, transformational leadership explains 67.1 percent of the variance and appears as the strongest set of qualities that play a vital role for innovation. Although transformational leadership is accepted widely in the literature as a leadership style in facilitating employee creativity and organisational innovation (García-Morales et al., 2012; Shin & Zhou, 2003), consideration leadership is recognised to a lesser extent. In contrast, this study has identified consideration leadership, which explains proportions of the variance 10.5 percent, as being a complement to transformational leadership in supporting employee creativity and innovation. This finding is consistent with other studies which emphasise that these two leadership behaviours increase leader effectiveness ratings, as they establish the leader as being stable and genuine in the view of the followers (Johnson et al., 2012). It is recommended that both leadership styles be incorporated into management training and development programmes. This study also recommends that Commonwealth departments recruit supervisors who have both of these leadership styles before implementing innovative projects. It is also important that future research identifies how both leadership styles impact on workplace innovation and to investigate successful workplace innovation practices to provide empirical evidence to support such relationships. Such a study is currently being completed by this research team.

Nevertheless, this paper has some limitations. This study is focused only on Australia which has predominantly an Anglo-Saxon culture. This limits the extent to which findings can be generalised as representative of all cultures. It would be interesting, in future studies, to investigate which leadership styles support innovation in the Eastern world. These eastern countries have been exposed to Confucian values, bureaucratic culture, high power distance, and autocratic decision-making style which discourage bottom-up innovation and encourage top-down innovation in public sectors (Kim & Lee, 2009; Lok & Crawford, 2004).

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Process of technology management in SMEs of the metal processing industry – the case study investigation

Elżbieta Krawczyk-Dembicka

A B S T R A C T

The main purpose of this work is to identify the factors that influence the process of technology management in the sector of small- and medium-sized enterprises of the metal processing industry, considering the shape and course required to achieve modern operation conditions by enterprises in the market.

The research process used the case study method, which was preceded by study visits to manufacturing enterprises, direct interviews with representatives of the management and employees of enterprises, and observations of the processing conditions.

The result of the research was the identification of technologies available and used in the analysed enterprises. It defines the process of technology management as well as the internal and external factors influencing this process and defines the timeline for the process of technology management.

The obtained results are the effect of the preliminary research, whose outcome will result in the development of issues related to technology management. They will be used to create a model of technology management, the assumptions of which will respond to modern needs and possibilities of manufacturing enterprises of the metal processing industry. The model can be used for practical application aimed at the provision of enterprises with innovation and competitiveness in the domestic and foreign markets.

K E Y W O R D S

technology management, models, metal processing industry, production enterprise

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Introduction

In modern enterprises of the metal processing industry, technology management is conditioned by company size and level of its competitiveness in the market. The bigger is the company, the more advanced is the level of development of the company. The same applies to the situation with technologies. Usually, companies from the sector of small- and medium-sized enterprises use the technologies available to the market, acquiring them together with purchased machinery and equipment and tailoring them to individual needs that depend on the profile of the business. Large companies usually develop their own technologies.

Manufacturing enterprises often perceive technologies as a possibility of using available processes

and the technological operation to create new products and meet the market demand. The research problem is, therefore, to determine how to define the technologies and the technology management.

The purpose of this study is the identification of external and internal factors influencing the technology management process in small- and medium-sized enterprises operating in the metal processing industry.

The study employs a case study methodology. Several data collection methods were utilized to prepare for the case study, i.e. direct observation (study visits), analysis of the enterprise documents, analysis of the archive materials, and direct interviews. Various sources of information considered during the formulation of conclusions of the study.

1. Review of the literature on technology management[1]

The development of manufacturing enterprises depends on their level of competitiveness in world markets. The level is largely conditioned by the access to technology and the ability to introduce innovative solutions. The correct integration of technologies in an enterprise should, therefore, be a source of a sustainable competitive advantage (Ejdys et al., 2015; Song et al., 2013). For this purpose, it is necessary both to understand the nature of technology as well as to determine the mechanisms shaping the process of technology management (Halicka, 2016; Mazurkiewicz et al., 2015).

Technology is a component of general knowledge on the types of techniques, methods of their formation, and practical implementation. It leads to gaining knowledge (often hidden or forbidden) and skills related to solving specific technological problems. In the literature, there are many different technology definitions relating to both its scientific significance and practical application. Cornwall (1977) defines technology as a resource of knowledge relating principally to the production of goods and services. Rosenberg (1982), in turn, talks about the understanding and implementation of previously acquired scientific knowledge on the types of techniques, methods, and structures. Dosi (1984) combines these two definitions and defines technology as a set of elements of practical and theoretical knowledge, skills of its application (know-how), methods, procedures and physical devices that use this knowledge. Polish authors predominantly define technology as the knowledge of manufacture methods required to produce a given product. In his work, Łunarski defines technology as "a directed process of producing the necessary products and services, implemented in a hierarchical production system with identified elements and their relationships, built for the realization of this process on the basis of the available theoretical and practical knowledge" (Łunarski, 2009, p. 202). The process approach to the subject is also presented by Santarek, who claims that technology is "a process consisting of many activities carried out in a strictly defined manner and sequence, resulting in the processing of input goods (raw materials, semi-finished products) into finished products having certain features and meeting customer needs" (Santarek, 2008, pp. 7-8).

From the definitions present in the literature as well as the amount and variety of technology existing on the market and the role that it fulfils in the modern economy, stems the need to develop mechanisms for technology management. The term technology management has been defined, among others by a team of researchers from the US National Research Council, which concluded that Technology Management (TM) combines the disciplines of engineering sciences and management sciences with the purpose of planning, development and implementation of technological capabilities, which will enable the implementation of strategic and operational objectives of the organisation (NRC, 1987, p. 2). The NRC team has also defined the key elements of technology management, which served other researchers in building the models of technology management. These are:

- identification and evaluation of technological options;
- project R&D management and the determination of its feasibility;
- integration of technologies into activities of the organisation;
- implementation of new technologies into products and/or services;
- obsolescence and replacement of technology.

One of the first authors carrying out research on the formulation of the model of technology manage-

[1] The chapter contents come from the introduction to the article to be published in *Procedia Engineering* (2017) as conference materials of the *7th International Conference on Engineering, Project and Production Management*, Poland, Bialystok, September 21-23, 2016. The original work: E. Krawczyk-Dembicka, *Analysis of technology management using the example of the production enterprise from the SME sector*.

ment was Gregory (1995, p. 350). He proposed a general model, including five major activities in the field of technology management of an enterprise, among which it is possible to distinguish identification, selection, acquisition, operation and protection of technology. Within each of the five activities, it is possible to extract several additional elements that, depending on the industry, will be subject to change. Within the framework of the technology identification process it is important to conduct a market analysis of the available technologies and find those that could have a significant impact on the development of the company. The next step is the selection and acquisition of the appropriate technology. All the activities related to the identification, selection, and acquisition of technology may take place inside or outside the company. The essential role is played by the human, technological and financial potential, at the disposal of a given entity. The other two activities (exploitation and protection of technology) are dependent solely on the conditions within the company and have an enormous impact on the generation of enterprise competitiveness.

Gregory's model has been supplemented or modified multiple times by other researchers. In most of the models, the differences are slight and limited to the change in classification and the recognition of the scope of individual activities. The differences also stem from the different understanding of some of the definitions. This indicates a lack of the ability to accurately classify concepts in the field of innovation management, knowledge management, and technology management. The common feature of all the described in the literature models is the determination of the general framework of technology management.

New insights are brought by researchers Pelser & Prinsloo (2014, p. 1), who noted that technology plays an important role in the interaction between entities (companies, research and development units), society and nature. Thus, they concluded that the current technological advances in the world could have serious implications for each of these entities and depend on their impact. Therefore, they agreed that technology management should be based on the development of the understanding of the issues concerning the relationships between individual units and identifying ways to rationally and efficiently utilize them.

The models currently described in the literature do not include the conditions prevailing in the modern economy. They do not define a clear process of the technology management but rather indicate its existence. The author of this work has undertaken to identify the factors that influence the process of the technology management in small-and-medium enterprises of the metal processing industry. This work leads to finding the common activities and relationships that create the process of technology management in the industry, independent of the size and structure of the company, but in relation to other variables, such as the cooperation between companies. The technology definition used in this study refers to the application of the knowledge on metal processing processes to the selection and modification of the production operations that are used in companies.

2. Research methods

Three study visits to each of the analysed manufacturing enterprises of the metal processing industry were carried out from June to September. During the visits, direct interviews were conducted with representatives of the company's management. In addition, documents made available by the enterprises were analysed. The collected information was supplemented by observations made in the various production departments. The research helped to identify several key factors influencing the manner of the technology management in small- and medium-sized enterprises.

The results are described in the case study of the enterprises. The basis for the formulation of the assumptions of the study was a critical analysis of literature. As a result, we selected three main elements, that created the structure of the case study:

1. characteristics of the enterprise and available technologies;
2. the manner of technology management in the enterprise;
3. the decision-making in the technology management.

The structure of the research process is shown in Fig. 1.

The section that includes the characteristics of enterprises and available technologies, analyses the functioning of the metal processing industry enterprise, identifies the types of technologies used, and studies their source of origin and funding.

The next stage was to determine the activities that are characteristic of the process of technology management already being used in the enterprise.

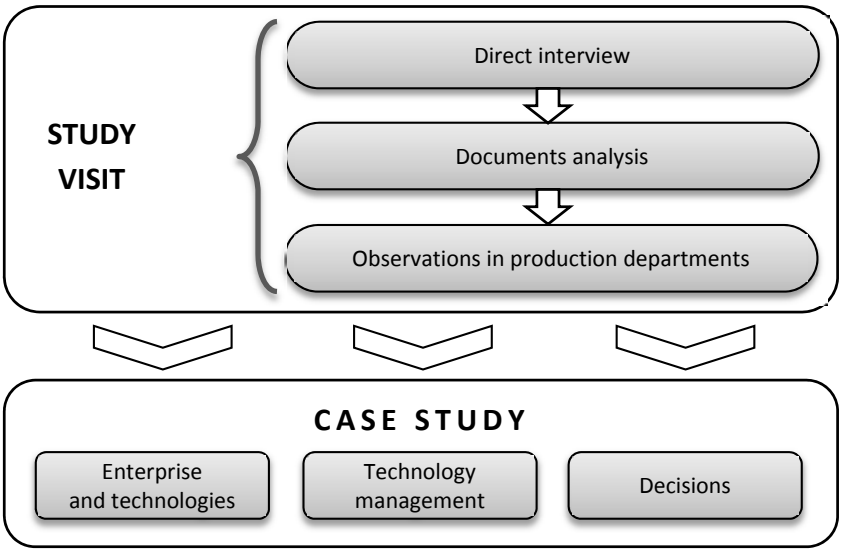

Fig. 1. Structure of the research process

The last stage was to determine the organisational structure of an enterprise, study who and at what stage of the process has the key influence on the decision-making, and to identify the factors that regulate the process of technology management.

3. Research results

For the needs of this study, two case studies of manufacturing enterprises of the metal processing industry were described, namely, one small and one medium company. The enterprises operate in Polish and foreign markets, have an outlined organisational structure, clearly defined development goals of the company, and formulated values. They use similar technologies.

The first of the analysed enterprises is a manufacturer of decorative and functional metal products. They are used in homes, gardens, and public places. The main customers of the company are trading networks, wholesale and landscape architects from the European Union and Eastern Europe. The company employs about 40 people. Considering the financial turnover, the company belongs to the group of small businesses.

The second of the surveyed enterprises is a manufacturer of machinery and technological equipment, used, among other things, in the construction of production lines. The enterprise also provides machining services for local entrepreneurs. Major customers are industrial concerns and the food industry. The company employs about 70 people and belongs to the group of medium-sized businesses.

The common factor connecting both enterprises is their policy, covering similar objectives and core values (Fig. 2). In general, they can be placed in one of these five main areas (1) the dialogue with customers and their satisfaction with the received products; (2) a well-supplied offer adapted to individual needs and customer requirements; (3) high efficiency of production that ensures the timeliness of orders; (4) taking care of the highest quality of products and services, and (5) investments into staff development and application of various types of motivating schemes to increase the employee involvement. One important element is the values respected within enterprises: (1) the knowledge and skills enabling the most innovative projects; (2) the effective teamwork ensuring proper implementation of the production process; (3) the involvement in the implementation of the enterprise goals, which has positive effects on the quality of solutions; (4) the aspiration for the permanent expansion of the company and investments in staff development; and (5) the safety and quality processing.

Analysis of the organisational structure of the enterprises unveils many similarities (Fig. 3). The management board is the governing body with one of the members acting as the technical director. The structure of enterprises has two main divisions: the Department of Economics, which includes the Human Resources Department and the Sales Department, and the Engineering Department, which has the Project Department, the Technology Department, the Production Department and the Storage Department.

This structured scheme provides a clear division of responsibilities of various departments and has an impact on the speed of decision-making. The expansion of the organisational structure has an influence on the time and the level of decision-making. The more complex is the structure, the more decision-making processes are needed at lower levels.

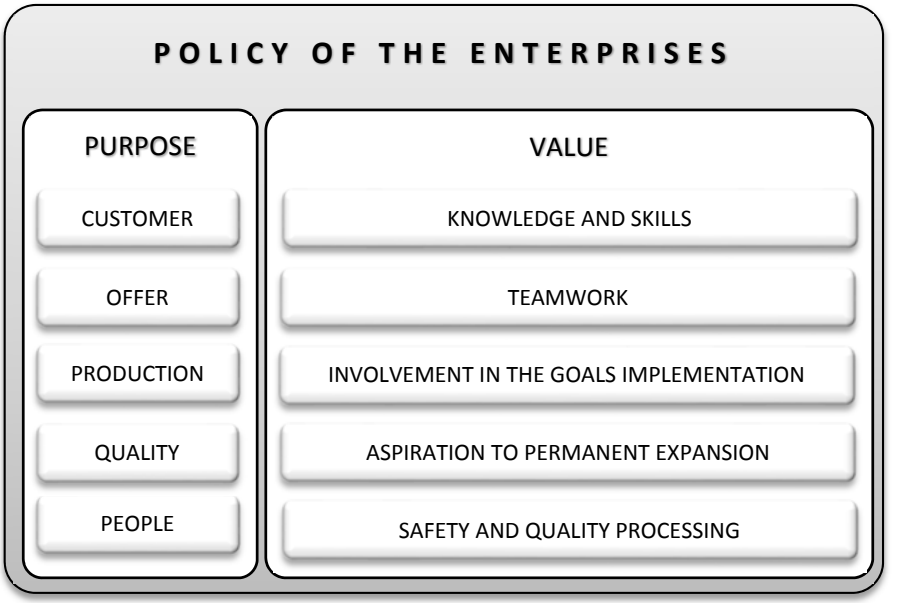

Fig. 2. Structure of the company policy

Source: own study based on company's materials.

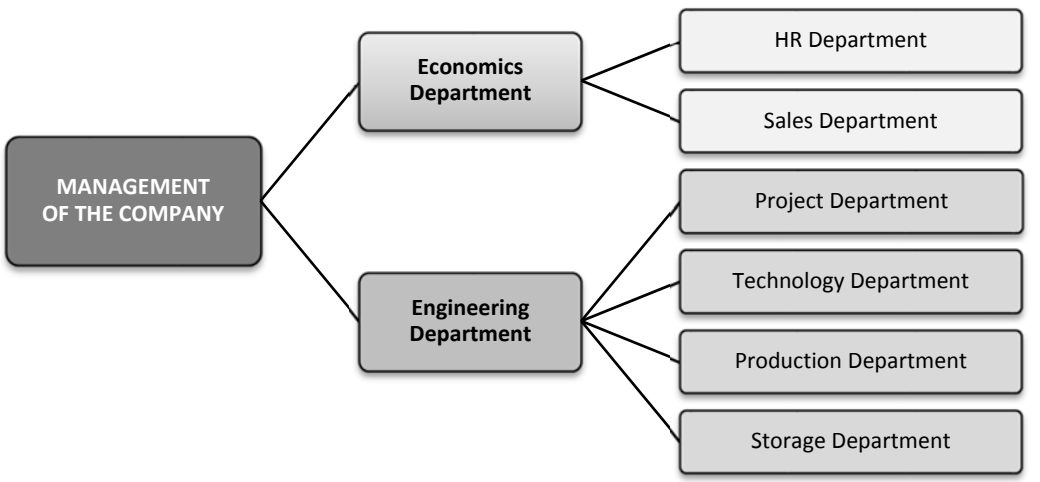

Fig. 3. General framework of organisational structure of enterprises

Source: own study based on enterprises materials.

The study visits and staff interviews identified several technologies used in the enterprises (Tab. 1).

Implementation of the technologies was associated with the use of ready-made solutions, commonly available in the market, such as the 5-axis milling. It was related to the purchase of new machinery and equipment necessary to fulfil orders placed by customers. Often, this resulted in the adjustment of the purchased machines for needs of the individual enterprise. The source of funding for new technologies was, in most cases, self-funding. This does not exclude public funding in the form of aid for modernization and expansion of production halls and equipment. The European Union support accounted for a small percentage of all spent funds. The implementation of new technologies is mainly determined by economic factors. As an enterprise has no visible evidence of the capabilities of a technology producing another product, it usually decides against their purchase.

The purpose of the study was to determine the process of developing a new technology, which would give the view of process technology management on the scale of the whole production and describe the work of enterprises. The process with the time perspective of individual activities is given in Fig. 4. The execution time of this process is from 3 to 6 months.

Tab. 1. Types of metal processing identified in enterprises

Technology groups	Types of technology
Surface treatment	– turning – milling – electrodrilling – drilling
Locksmithing treatment	– semi-automatic and automatic grinding – manual grinding
Profiling treatment	– cutting sheets (water, laser, scissors, wire) – cutting profiles (bandsaw) – bending – forming – rolling – grooving
Thermal treatment	– hardening
Connecting materials	– welding (TIG/MIG, laser)
Other	– liquid painting – powder painting – quality control

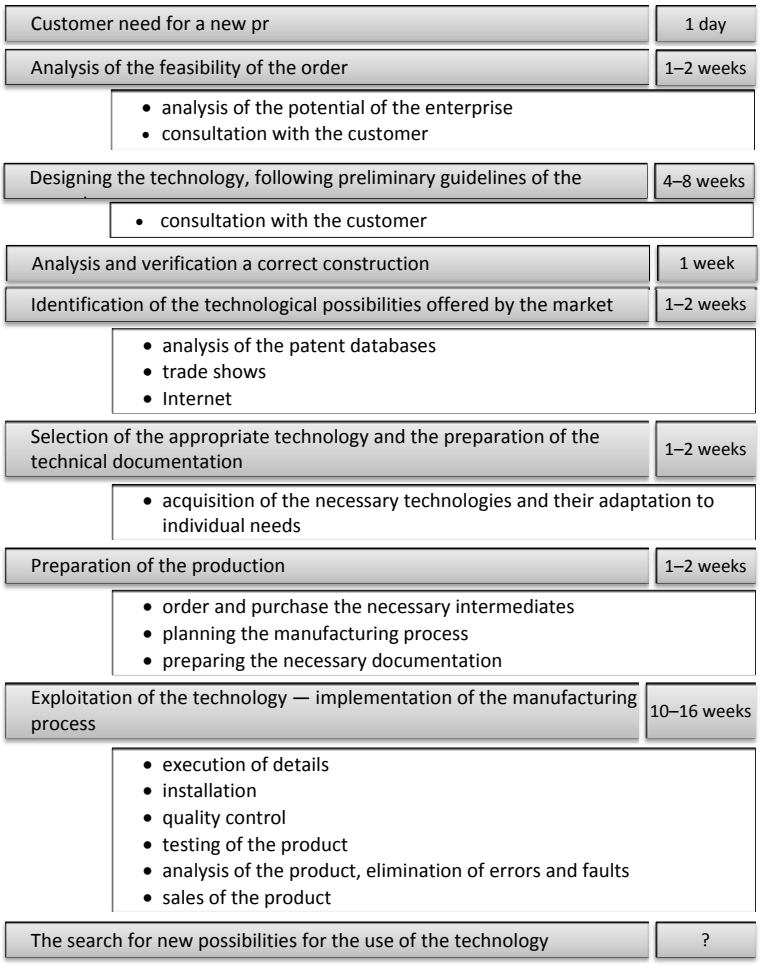

Fig. 4. Process for the development of a new technology

4. Discussion of the results

The reason for the appearance of most technologies in the small- and medium-sized enterprises in the metal processing industry are customer needs. The conducted process demonstrates the existence of a clear sequence of events, aimed at the development a new technology. The decision-making about the manner of technology management (or the development of a new technology) and the course of the process, takes place mainly at the level of enterprise management. In some cases, managers consult with the engineers and technologists, whose aim is to provide an in-depth analysis of the technology. In this part of the study, the analysis of the research results is presented.

The method of the process management depends on several external and internal factors that affect the conditions of the enterprise. The most important internal factors include:

- qualifications of the enterprise workers;
- technological possibilities of the company;
- financial capabilities of the company related to the acquisition of new technologies;
- the economic viability of implementation of the new technologies;
- the scope of ongoing contracts;
- the size of production series;
- the available machinery park;
- manufacturing capabilities of the enterprise;
- quality factors of the used technologies.

Apart from internal factors, the external factors also play an important role, which shows the impact of the environment on the functioning of the company in the market. These include:

- the possibility to acquire technology from the market;
- possibilities of cooperation with other production enterprises in the industry;

- the market prices of purchase machinery, equipment, materials, technologies (the costs of introducing new technology);
- possibilities of adaptive technology to other objectives realised by the enterprises.

The above-mentioned factors are an important element influencing on the shape and course of the process of technology management, in production enterprises from the metal processing industry in the sector of small- and medium-sized enterprises. They correspond to different turbulence in the industry and describe the environment of the company.

Conclusions

In small- and medium-sized enterprises from the metal processing industry, the linear process of technology management is clear. This process is the part of the manufacturing process, which aims to produce a new product, corresponding to the clearly defined requirements and customer needs. Enterprises are guided primarily by economic factors that determine the cost effectiveness of the acquisition and implementation of new technologies, as well as the possibility of its adaptation for other goals of the companies.

All decision-making processes related to technology management are in the hands of the company management. They are dependent on the size and organisational structure. The more complex is the structure, the more decision-making processes are needed at lower levels, and the management focuses mainly on the financial decisions concerning the acquisition of new technologies. The Management also has the final say on the implementation of the technologies. The possibility of adaptive technologies that are available in an enterprise is influencing the development of new products and technologies.

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Context of the inventory management expenses in the case of planned shortages

János Korponai, Ágota Bányainé Tóth, Béla Illés

A B S T R A C T

The main purpose of the paper is to present the relations between the different cost factors of the inventory management systems, and the context between the order quantities and the cost level. The theoretical approach of the model assumes a deterministic operational environment with planned shortages. We make the examination of the contexts by applying the ceteris paribus principle; we change only one cost factor from among the initial conditions at once and examine its effect on the cost level.

By using the economic order quantity with the planned shortage model, we can define the optimal order quantity, along which our stock management can be guaranteed by the most favourable cost level. The optimisation of the inventory level and the inventory management expenses together means an important factor in the competitiveness of the company. During the definition of the optimal inventory level of purchased parts, the purchasing and stock holding costs, and also the consequence of shortages play an important role. The presentation of the specific expense factors in each other's function, and the representation of the onetime order expenses show their proportion compared to each other and the effect of their change on the total cost, and define the opportunities of the optimisation. The significance of the model is that it represents the level line of costs, the movement of the different cost factors in relation to others and their operating mechanism. Thus, it facilitates the representation of costs and the definition of the direction of optimisation.

K E Y W O R D S

cost factor, optimum, order quantity, purchasing, shortage, stock holding

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Introduction

It often happens in practical logistics that the actual utilisation demand cannot be satisfied immediately. The continuity of service, in some cases, is broken by a disturbance in a stage of the supply chain, which causes a significant confusion for both the customer and the supplier. In other cases, the reason is a planned stock management strategy that can be led back to a certain aspect of economic efficiency.

The classical stockpile management approaches the optimisation of the stock level from the side of expenses, meaning that the optimal stock level is represented by the stock derived from the lowest total costs. Among the costs of the stockpile management system, we differentiate three basic cost categories:

- cost elements related to the procurement activity,
- costs related to stock holding,
- costs related to stock shortage consequences (Krampe et al., 2012).

These three cost groups can be modified to the detriment of one another (Halászné, 1998; Kummer et al., 2009). The holding costs increase linearly with the increase in the lot size, while the costs related to procurement decrease with the increase in the order quantity (Tersine & Barman, 1991). Similarly, the holding costs are in a trade-off relation with the costs of stock shortage. The task is the definition of the optimum of the total costs function that fulfils the cost-minimising target, and the quantification of the derivable order quantity and of the order period (Koltai, 2009).

1. Literature review

The first scientific model about an optimal lot size determination was published by Harris in 1913, in the article "How many parts to make at once" (Harris, 1913). This model defines the production quantity optimisation with not acceptable stock-out periods and assumes deterministic conditions. Several extensions of the basic Economic Order Quantity model are defined since that, describing the real operational processes more and more in details, and gives answers to the practical issues. In the case of deterministic inputs, the model is extended to the analysis of the deterioration of goods (Ghare & Scharder, 1963), the quantity discounts (Tersine & Barman, 1991), limited supplier capacity, the dynamic version of the economic lot size (Wagner & Whitin, 1958), etc., and some research has also focused on the direction of stochastic factors, such as the demand fluctuation, the lead time variation, the fraction of the defective items (Porteus, 1986) or shortages using a probability density function, etc. Chang and Dye applied the model for deteriorating items, where the time-varying demand is partial backlogged (Chang & Dye, 1999).

The initial assumption of Harris's basic model that shortages are not allowed is too restrictive in real industrial working environment. Many researchers (Park, 1982; Hollier & Mak, 1983; Grubbström & Erdem, 1999) assume that during shortage periods all demand either backlogged or lost. Deb and Chaudhuri extended the economic order quantity model by including completely backordered shortages (Deb & Chaudhuri, 1987). They defined a replenishment policy where the inventory cycles were divided into two periods, in the first one the demand is covered by inventory, while in the second part of the cycle it is followed by a period of shortages. In their model shortages were allowed in all cycles except the final one. Also Dave worked out a heuristic inventory-replenishment model with planned shortages and linearly increasing demand (Dave, 1989). Teng and Yang considered a partial backlogging rate during the stockout periods when demand and cost are fluctuating with time (Teng & Yang, 2004). Many researchers extended the planned shortage model by considering varying shortage cost values (Wee et al., 2007), and also assuming deteriorating items with imperfect quality (Salameh & Jaber, 2000; Wee et al., 2006; Eroglu & Ozdemir, 2007).

2. Research methods

By walking around the initial conditions of the economic order quantity model with planned shortages, we analyse the context of the inventory management expenses. We make the examination of the contexts by applying the ceteris paribus principle; we change only one cost factor from among the initial conditions at once. First we describe the context of the inventory cycle model with planned shortages, and define the calculations methods of the different cost factors. The main purpose of our analysis is to define the economic order quantity, the optimum backorder level and the optimum level of different cost factors, and also to present the relation between the cost factors. By introducing a multiplying factor derived from the relation between the costs of stock holding and stock shortage the optimal quantity analysis can be simplified to the basic model made up of one purchase and stock holding cost.

3. Research results

3.1. Determination of the economic order quantity in the case of a planned shortage

As an initial condition, we define that the unsatisfied demand due to stock shortage can be rescheduled by a defined cost level, and it will be fully performed at a later date (Vörös, 1991). The main questions of stock management models are the optimum quantity that can be procured on one occasion

by most favourable total costs, and the optimal scheduling of procurement. The balance between the stock level and the costs can be defined using the economic order quantity with a planned shortage model, having the following initial conditions (Halászné, 1998; Kummer et al., 2009; Krampe et al., 2012; Koltai, 2009; Vörös, 1991; Illésné, 1998; Szegedi & Prezenszki, 2003):

- The supply rate can be considered being infinite; the stock replenishment is immediate, and so the replenishment time equals zero;
- The ordered quantity arrives as one item; frequency of supplies is scheduled for identical periods;
- The demand is known and pre-definable with absolute certainty;
- Both the customer and the supplier want to satisfy the demand. The demand is continuous, and the utilisation has a consistent intensity; thus, the demand rate is constant. Accordingly, within a supply period, the stock level shows a strictly monotonous descending linear function in relation to time;
- The stock shortage is accepted at a certain cost;
- The ordering costs are independent of the order quantity;
- The holding costs per unit are constant, and they change linearly with the stock quantity;
- By assuming an infinite time horizon, the costs are independent of the time factor;
- The purchase price per unit does not depend on quantity; thus, the purchase price does not influence the stock management policy to be chosen (Vörös, 2010; Chopra & Meindl, 2007).

In the case of a constant utilisation demand with continuous and uniform intensity (Fig. 1. a) and a procurement cycle with uniform period intervals, if the opening stock d of period t is smaller than the total utilisation demand q during the period, the stocks before the next period will decrease to zero at a certain t_0 point of time, followed by a stock shortage period with the t_2 length, at the end of which the stocks will be replenished. During the period t_2, the continuous demand will lead to a backlog of the level s.

In one diagram, Figure 1. b) summarises the arrival of stocks and the development of demands in relation to time as a cumulated value. The difference between these two values shows the relation between the demands satisfied on time and the demands that are rescheduled.

The purchase costs incurring during the whole analysed period can be defined by multiplying the one-off purchase cost by the frequency of procurements (Kulcsár, 1998):

$$C_o = \frac{Q}{q} \cdot c_o \tag{1}$$

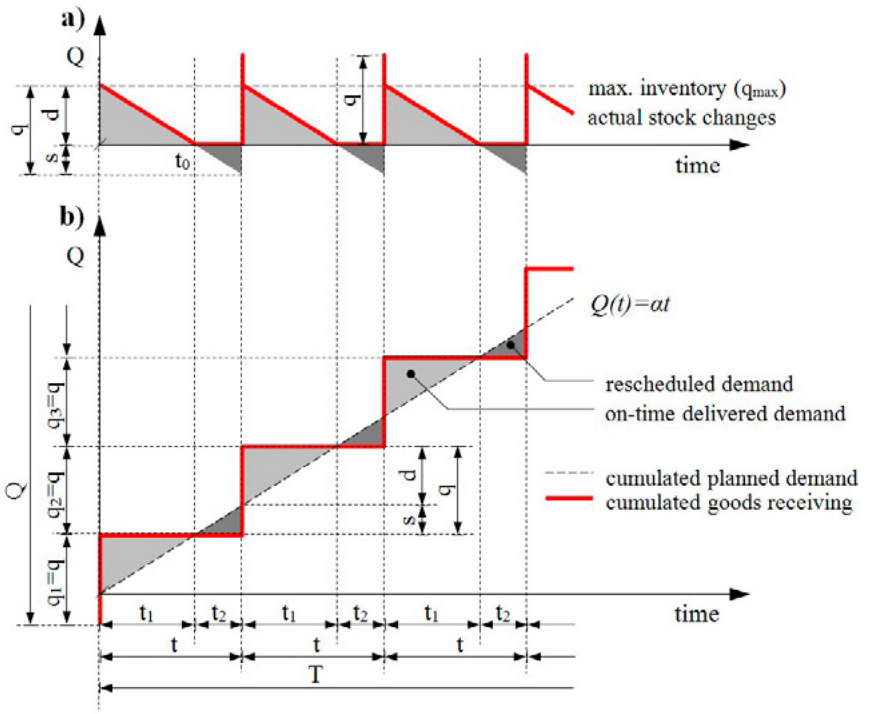

Fig. 1. Optimal stock level in the case of regular stock replenishment and demand with uniform intensity with periods of stock shortage

where:
C_o – the total purchase cost for the examined period,
Q – the total purchase demand for the examined period,
q – the purchase demand for a single period, economic order quantity,
c_o – the cost of a single purchase order.

The holding costs can be defined using the area of sections due to the t_1 period of the sawtooth diagram (Kulcsár, 1998):

$$C_h = \frac{1}{2} \cdot d \cdot t_1 \cdot \frac{Q}{q} \cdot c_h = \frac{1}{2} \cdot d^2 \cdot \frac{T}{q} \cdot c_h = \frac{d^2}{2 \cdot q} \cdot v \cdot r \quad (2)$$

where:
C_h – the total holding cost for the examined period,
d – the portion of the demand covered by stock within one single period,
t_1 – the period, during the demand is performed without delay at the time of its occurrence,
c_h – the holding cost per time unit,
T – the length of the complete period,
v – the purchasing price per unit,
r – the annual holding cost rate.

During the quantification of the stock shortage costs, we must start from the relation that the continuous demand increases the level of the backlog, which can be expressed using the area of sections due to the period t_2 of the sawtooth diagram (Krampe et al., 2012; Kulcsár, 1998):

$$C_s = \frac{1}{2} \cdot (q-d) \cdot t_2 \cdot \frac{Q}{q} \cdot c_s = \\ = \frac{(q-d)^2}{2 \cdot q} \cdot T \cdot c_s = \frac{s^2}{2 \cdot q} \cdot T \cdot c_s \quad (3)$$

where:
C_s – the shortage cost during the whole analysed period,
t_2 – the period, during which the demands due must be rescheduled for a later date,
c_s – the shortage cost per time unit.

The basic model of the economic order quantity starts from the relation that the purchase cost, the holding cost changes, and the stock level change according to the order quantity. Accordingly, the more rarely orders are made, the more favourable the purchase costs are per unit, and at the same time, the holding costs are increasing linearly (Vijayan & Kumaran, 2009; Jaynes, 2003). The function of total costs can be defined as the sum of these three costs and the value of the purchased parts. The objective function is defining the minimum of the function of total costs (Koltai, 2009; Kummer et al., 2009; Vörös, 2010; Krampe et al., 2012; Chopra & Meindl, 2007; Kulcsár, 1998):

$$C'(q;d) = Q \cdot v + C_o + C_h + C_s = \\ = \frac{Q}{q} \cdot c_o + \frac{d^2}{2 \cdot q} \cdot T \cdot c_h + \frac{(q-d)^2}{2 \cdot q} \cdot T \cdot c_s \rightarrow min \quad (4)$$

where:
C' – the total cost of inventory management for the examined period, with the value of purchased items.

The optimal order quantity can be defined by solving the system of previous equations, where the form of partial derivatives according to q and d of the function of total costs is set equal to zero (Krampe et al., 2012; Vörös, 1991; Kulcsár, 1998; Huang & Wu, 2016; Paknejad et al., 2015; Cárdenas-Barrón, 2010):

$$q = d \cdot \frac{c_h + c_s}{c_s} = \sqrt{\frac{2 \cdot Q}{T} \cdot \frac{c_o}{c_h}} \cdot \sqrt{\frac{c_h + c_s}{c_s}} \quad (5)$$

The on-time delivered quantity can be calculated as followed:

$$d = \sqrt{\frac{2 \cdot Q}{T} \cdot \frac{c_o}{c_h}} \cdot \sqrt{\frac{c_s}{c_h + c_s}} \quad (6)$$

The optimal amount to be backordered (Vörös, 2010):

$$s = q - d = q \cdot \frac{c_h}{c_h + c_s} = \sqrt{\frac{2 \cdot Q}{T} \cdot \frac{c_o}{c_s}} \cdot \sqrt{\frac{c_h}{c_h + c_s}} \quad (7)$$

The minimum total cost incurring during the whole period together with the money spent on purchased stocks (Stock & Lambert, 2001; Krampe et al., 2012; Vörös, 1991; Kulcsár, 1998):

$$C' = \sqrt{2 \cdot Q \cdot T \cdot c_o \cdot c_h \cdot \frac{c_s}{c_h + c_s}} + Q \cdot v \quad (8)$$

If the purchase price of the items does not change during the time and it is independent of the ordered volume, the annual purchase value can be considered as constant, so the equation can be simplified. The function of the total costs can be defined by replacing the time factors, and this relation will have a role in the future analysis:

$$C(q;d) = \frac{T}{t}\cdot c_o + \frac{{t_1}^2}{t^2}\cdot\frac{T\cdot q}{2}\cdot \cdot c_h + \frac{{t_2}^2}{t^2}\cdot\frac{T\cdot q}{2}\cdot c_s \rightarrow \min \quad (9)$$

where:

C – the total cost of inventory management for the examined period, without the value of purchased items.

The purchase cost of the analysed period can also be defined as follows:

$$C_o = \sqrt{\frac{Q\cdot T\cdot c_o\cdot c_h}{2}}\cdot\sqrt{\frac{c_s}{c_h+c_s}} \quad (10)$$

The cost of stock holding incurred during the whole analysed period can also be defined with full knowledge of the purchase cost as follows:

$$C_h = \frac{c_s}{c_h+c_s}\cdot\sqrt{\frac{Q\cdot T\cdot c_o\cdot c_h}{2}}\cdot \cdot\sqrt{\frac{c_s}{c_h+c_s}} = C_o\cdot\frac{c_s}{c_h+c_s} \quad (11)$$

The cost of stock shortage incurred during the whole analysed period can be defined with full knowledge of the purchase cost with the following relation:

$$C_s = \frac{c_h}{c_h+c_s}\cdot\sqrt{\frac{Q\cdot T\cdot c_o\cdot c_h}{2}}\cdot \cdot\sqrt{\frac{c_s}{c_h+c_s}} = C_o\cdot\frac{c_h}{c_h+c_s} \quad (12)$$

By replacing the above-mentioned relations in Formula (4) without the value of the purchased items, the total costs of the whole analysed period can also be defined with full knowledge of the purchase cost:

$$C = C_o + C_o\cdot\frac{c_s}{c_h+c_s} + C_o\cdot\frac{c_h}{c_h+c_s} = \quad (13)$$

$$= C_o\cdot\left(1+\frac{c_s}{c_h+c_s}+\frac{c_h}{c_h+c_s}\right) = 2\cdot C_o$$

Relations (4) and (13) show that in an optimal balanced state, the purchase cost represents half of the total costs, while the other half is the sum of the costs of the stock holding and stock shortage. The following relation can be derived:

$$\frac{C}{2} = C_o = C_h + C_s \quad (14)$$

3.2. Relation between cost factors and level lines

In the case of the model allowing a stock shortage able to supplement a backlog in one batch, the whole stockpiling period can be divided into two periods, the one covered by stocks and the one with the stock shortage. The length of the periods is determined by the level of the specific cost projected onto the time units, and their proportion within the whole stockpiling period is given by the ratio of the two cost groups. The bigger the respective cost factor, the bigger is the extent of the occurrence period to be shortened. When the two cost factors are on the same level, their occurrence length is balanced as well, meaning that the alternating periods covered by stocks and with stock shortage have the same length.

The optimal cost level can be reached at the ratio where the different special costs together with their length of occurrence reflect the lowest level, thus, where the sum of C_h+C_s is the lowest.

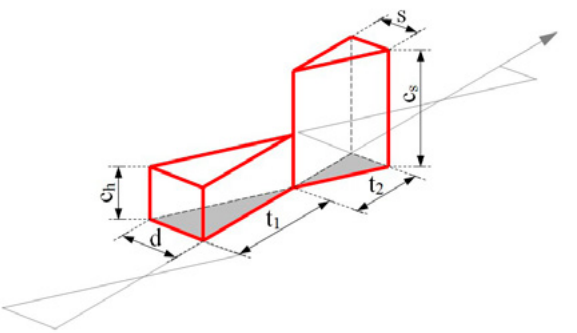

Fig. 2. Relation of holding and shortage costs and intervals within one period

The different specific cost factors and the period attributable to them can also be interpreted as a triangular-based prism, the bases of which are the stock level and the time profile of the backlog, while its height is given by the multiplier of the specific costs

attributable to the respective period. The balanced state of the volume of these two bodies is formed, where their joint volume has the smallest value (Fig. 2).

In case we quantify the different volumes, we can see that the result is identical with the formula for different stockpiling periods at the models with the stock shortage, for which we seek the minimum value:

$$\frac{1}{2}\cdot d\cdot t_1\cdot c_h+\frac{1}{2}\cdot s\cdot t_2\cdot c_s\ \rightarrow\ \min \qquad (15)$$

The following equation shows the minimum stock holding and stock shortage for one stockpiling period:

$$\frac{1}{2}\cdot q\cdot t\cdot\left(\frac{c_s}{c_h+c_s}\right)^2\cdot c_h+\frac{1}{2}\cdot q\cdot t\cdot\left(\frac{c_h}{c_h+c_s}\right)^2\cdot c_s=\frac{1}{2}\cdot q\cdot t\cdot c_{(c_h;c_s)} \qquad (16)$$

where:

$c_{(c_h;c_s)}$ – the optimal ratio of specific costs of stock holding and stock shortage projected on the stockpiling period.

The solution of the equation results in the multiplier, which shows the most favourable cost level during the stockpiling period:

$$c_{(c_h;c_s)}=\frac{c_h\cdot c_s}{c_s+c_s} \qquad (17)$$

The significance of this relation is that during the modelling, the costs of stock holding and stock shortage can be replaced by a single multiplying factor, thus the analysis can be simplified to a basic model made up of one purchase and stock holding cost.

By assuming a consistent and continuous utilisation demand, this can also be interpreted as calculating a single volume from the volume attributed to the two periods, where the base of the triangular-based prism is the whole stockpiling period t and the quantity q, and its height is given by the multiplier (Fig. 3).

It is useful to show the cost factors as a function of one another. Figure 4 shows the specific cost of stock shortage in relation to the specific cost of stock holding. The diagram must be interpreted as showing the joint cost levels attributable to the different relations of these two specific cost factors. The thick red continuous curve shows the joint costs of stock holding and stock shortage by the respective specific cost levels c_h and c_s. The cost indicated with the continuous

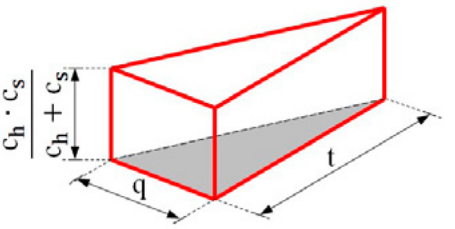

Fig. 3. Replacement of stock holding and stock shortage costs by a multiplying factor of a weighted specific cost

line reflects the same level at every point of the curve, which means that a given cost level in case of a higher stock holding cost factor can be reached only by a lower stock shortage cost factor. These convex curves with a negative slope show single level lines that reflect an increasing value when distancing from the initial point.

We can see that the cost curve in the direction of both specific cost factors is limited form below within the set of positive numbers. The function also has quantifiable values within the range below the limit value, but the result shows a negative value. The negative section of the function falls out of the domain since this would mean that we would have to calculate with negative stock holding and stock shortage costs, which cannot be interpreted in practice. The lower limit values also mean that optimisation can be realised only within a given range, which is the optimisation range. The lower limit values above zero also mean that by assuming a fixed quantity q, in the case of every $0<c_h<1$ there is a stock holding and stock shortage period with a certain length.

When defining relation (14), we saw that the total cost of stock management reaches its minimum where the purchase cost is identical with the joint costs of stock holding and stock shortage. This also proves that every point of the continuous red curve is identical in the case of the given level line with the half of stockpiling cost C attributable to a defined quantity q, which results from $C=C_o+C_h+C_s$ and $C_{h;s}=C_h+C_s$ and $C_{(min)}=>C_{h;s}=C_o$.

The initial condition of the model is that factors q, Q, T, and c_o are fixed values, which means that the value t is also fixed. Thus, only cost factors c_h and c_s, levels d and s, and the length of time periods t_1 and t_2 can be changed. Since values c_o, Q and q are constant, the derivable purchase cost C_o is constant too, which, in optimal cases, is identical with the half of all stockpiling costs, an equality that was proved with relation (13). The definition of the minimum level of total costs is the task.

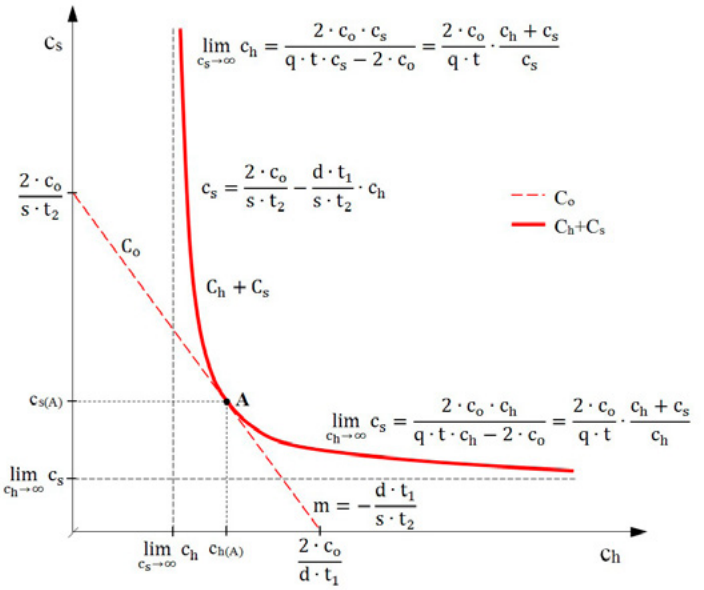

Fig. 4. Relation between cost factors and the level line, representation of the optimal point and of limit values

The costs related to purchases can be drawn onto the diagram as well. The dotted red line shows the purchase cost C_o, which, in the case of a fixed q value is independent of factors c_h and c_s. The line shows an identical level at every point. Its slope is the result of the ratio of the average stock level and the average backlog quantifiable during the period of stock holding and stock shortage.

In an optimal balance state, the purchase cost is identical to the sum of stock holding and stock shortage costs.

$$\frac{Q}{q}\cdot c_o = \frac{1}{2}\cdot d\cdot t_1\cdot\frac{Q}{q}\cdot c_h + \frac{1}{2}\cdot s\cdot t_2\cdot\frac{Q}{q}\cdot c_s \qquad (18)$$

By rearranging the equation, we can get the following equality, which shows the cost of stock shortage c_s in relation to stock holding c_h:

$$c_s = \frac{2\cdot c_o}{s\cdot t_2} - \frac{d\cdot t_1}{s\cdot t_2}\cdot c_h \qquad (19)$$

The slope of purchase cost line C_o can be directly defined by this formula:

$$m = -\frac{d\cdot t_1}{s\cdot t_2} \qquad (20)$$

where:

m – the slope of the purchase cost.

The points of intersection of the purchase cost axis can be defined from Formula (19); thus, the purchase function can be shown with knowledge of the slope and the points of intersection:

Vertical axial section: $\frac{2\cdot c_o}{s\cdot t_2}$ (21)

Horizontal axial section: $\frac{2\cdot c_o}{d\cdot t_1}$ (22)

The optimal total costs can be given using the relation $C=C_o+C_h+C_s$ and in balanced state with $C_o=C_h+C_s$ and the result of rearranging the two formulae, as proofed in the Formula (13):

$$C = 2\cdot C_o \qquad (23)$$

The equality can be given by replacement as follows:

$$\sqrt{2\cdot Q\cdot T\cdot c_o\cdot c_h\cdot\frac{c_s}{c_h+c_s}} = 2\cdot\frac{Q}{q}\cdot c_o \qquad (24)$$

Within a positive domain, Formula (24) allows us to deduct the lower limit values of the different specific cost factors; these fix the position of curve C_h+C_s and close the optimisation range:

$$\lim_{c_s\to\infty} c_h = \frac{2\cdot c_o\cdot c_s}{q\cdot t\cdot c_s - 2\cdot c_o} = \frac{2\cdot c_o}{q\cdot t}\cdot\frac{c_h+c_s}{c_s} \qquad (25)$$

$$\lim_{c_h\to\infty} c_s = \frac{2\cdot c_o\cdot c_h}{q\cdot t\cdot c_h - 2\cdot c_o} = \frac{2\cdot c_o}{q\cdot t}\cdot\frac{c_h+c_s}{c_h} \qquad (26)$$

The diagram behaves similarly to the indifference curves and the budget line known from microeconomics (Kopányi, 1996; Böventer, 1991), but we must emphasise that in practice, there is no substitutability between the specific cost of stock holding c_h and the specific cost of stock shortage c_s, since the modification, e.g. increase of a cost factor will not result in the decrease of the other; within an optimisation, only the ratio of periods t_1 and t_2 will shift in one direction. The significance of the model is that it represents the level line of costs, the movement of the different cost factors in relation to others, and their operating mechanism; thus, it facilitates the representation of costs and the definition of the direction of optimisation.

In case factors c_h and c_s keep their original ration and increase from the point $c_{h(A)};c_{s(A)}$ to the point $c_{h(B)};c_{s(B)}$, the value of q, by a higher cost level C_h+C_s, will remain unaltered. Figure 5 shows the shifting

between the level lines when distancing from the initial point. Each point of the dotted straight line drawn from the initial point reflects a similar ratio of specific costs c_h and c_s, the further from the initial point the higher the cost levels shown by the level lines, thus the points of intersection of the straight line and of the different level lines show the proportionate changes in specific costs c_h and c_s.

In a balanced state, a purchase cost line $C_{o(B)}$ can be drawn to the higher level line, the slope of which remains identical with the slope of the line $C_{o(A)}$ due to the invariability of the c_h;c_s ratio. In case the two specific cost factors become more expensive, their impact on purchase would result in more frequent purchases by smaller q quantities. Since quantity q was fixed among the initial conditions, a purchase line drawn to a higher-level line in a balanced state can be drawn only by a higher one-off purchase cost c_o. However, the alteration of c_h;c_s in practice does not influence the one-off purchase cost c_o, making it clear that the balanced state does not reflect an optimal state. To achieve the optimal state, we must lift the fixedness of q, and the order quantity could be optimised by a new q value. In practice, however, we could face the situation when the fixedness of q cannot be lifted, e.g. the deliveries cannot be organised to be more frequent. This state cannot be considered as an optimal one.

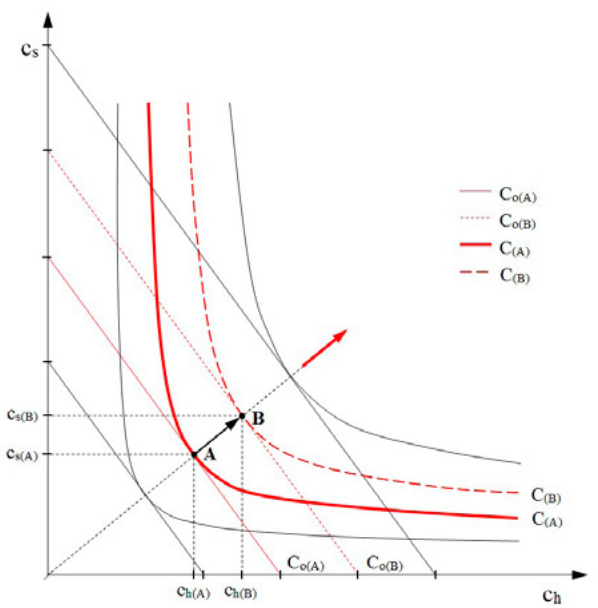

Fig. 5. Shift of the level of the total costs in the case of a proportionate change of the specific stock holding and stock shortage costs

Another interpretation of Figure 5 is that instead of a proportionally changing a specific stock holding cost c_h and a specific stock shortage cost c_s, it is the one-off purchase cost c_o that changes. In case the one-off purchase cost c_o increases, it would result in an increased purchase cost $C_{o(B)}$ by an unaltered purchase frequency. This can be reduced by making the purchases less frequent, which would lead to the increase in delivery quantities and the increase in the average level of stocks. Since the one-off purchase cost c_o does not influence factors c_h;c_s, the modification of c_o affects the joint level of costs C_h+C_s only through the q purchase quantities. In case quantity q is fixed, we can see that the new state is not optimal, since the frequency of purchases must be changed for optimisation, which cannot be realised due to the fixedness of quantity q.

In the case of a change of only one of the specific costs c_h and c_s, the ratio of time periods t_1 and t_2 will change as well. A shift is not possible on the curve C_h+C_s representing a similar cost level since the shift on the curve could be achieved only by a shift in the opposite direction of the other cost factor. However, since these two specific cost factors do not replace each other in practice, the alteration of one factor does not cause the shift of the other factor in the opposite direction. Thus, costs C_h+C_s will show a new level line in this situation. In case the value of the specific cost factor increases, the distance between the level line and the initial point grows (Figure 6).

The line of the purchase cost $C_{o(B)}$ can also be drawn as a tangent line to the points $c_{h(B)}$;$c_{s(B)}$ of the new level line. The level line and the tangent point of the line give the optimum to the new values $c_{h(B)}$;$c_{s(B)}$. In case only one of factors c_h and c_s changes, or both do in a way that their ratio changes as well in a certain direction, the slope of the purchase cost $C_{o(B)}$ drawable to the curve indicates the new level change. This is the result of the fact that the ratio of time periods t_1 and t_2 is rearranged due to the shifting of the specific cost of stock holding from the specific cost of the backlog; thus, the amount of optimum order quantity will change for the whole period. To draw the tangent line to the new level line, we must lift the fixedness of q among the initial condition, otherwise, the purchase cost $C_{o(B)}$ would remain unaltered, which must be made equal to the new cost level to achieve balance.

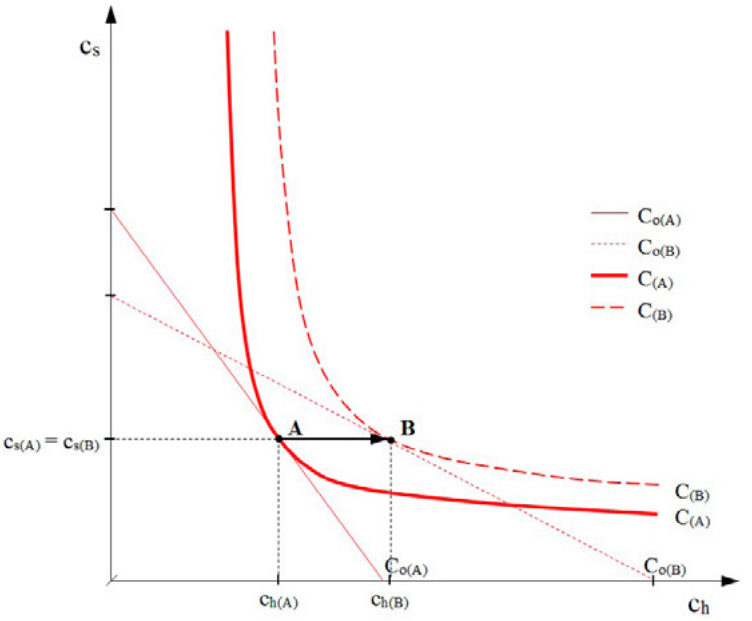

Fig. 6. Modification of the level line of total costs in the case of an alteration of the specific stock holding cost

Conclusions

It often happens in practical logistics that either the ordering cost or the inventory holding cost and stock-out cost change with the time. In each case, it is necessary to draw the purchase line and the positions of cost factors c_h and c_s to examine the initial point and to discover the possibility of optimisation. In case these do not coincide, the initial state does not reflect an optimal state. Optimisation must be carried out with knowledge of the modifiable parameters and along the described operating mechanism. In case one has fixed a single factor among the factors necessary for optimisation, the optimum cannot be reached.

By using the described model, we can define the optimisation range of the different cost factors of the inventory management system, and also the direction of the optimisation. The model represents the level line of costs, the movement of the different cost factors in relation to others and their operating mechanism.

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Courier service quality from the clients' perspective

Aleksandra Gulc

ABSTRACT

The aim of the study is a critical analysis of literature concerning the evaluation of courier service quality and verification if client expectations towards courier service quality change in time considering the perspective of future 5–10 years. Research methods include the theoretical analysis of scientific literature, CAWI survey and statistical analysis of obtained data.

The literature overview has shown the lack of clearly defined evaluation constructs of courier service quality together with the criteria and weight, one universal commonly used measuring scale for evaluation of the service quality, diversification of methods and measurement tools for the various groups of stakeholders of courier service. Moreover, it can be concluded that the research concerning the courier service quality has not considered the problem of aging of quality indicators. Research results by the author have proved that the expectations of clients using courier service change in time, some of them are exposed to the aging process (price) while others become more important (for example tele-technologies, modern packaging, and technical facilities). Moreover, the survey results have shown that the customer opinions can be the source of interesting and innovative ideas for the development of courier service in future.

The analysis of domestic and foreign literature allowed presenting the academia with an output concerning the evaluation of quality in the field of courier service. As a result, the theoretical and methodological gaps were revealed to expose potential fields for further research. The research results concerning different methods of service quality evaluation can be useful mainly for managers in courier enterprises. Moreover, the knowledge about changing expectations of clients allows adjusting courier proposals to customer needs to gain a competitive advantage in the global market.

KEY WORDS

courier service quality, criteria, evaluation

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Introduction

Recently, the courier, express and parcel market (CEP) has developed dynamically worldwide. For example, in Poland, in the period 2000–2015, the number of registered courier operators increased by 1400%, while the volume of deliveries and revenue grew at double-digit pace (Urząd Komunikacji Elektronicznej, 2016). In the next few years, the global CEP market is expected to grow by 3.5% reaching the value of USD 385.09 billion by 2019 (Global Courier…, 2014). Although courier services stand at the juncture of logistics and postal services, they have characteristic features, which differentiate them, for example, the specified delivery time with an accuracy to an hour, money back guarantee, receipt of the shipment, delivery to the addressee in door-to-door sys-

tem, the ability to track the shipment in the tracking-tracing system, the role of specific messenger – courier. This specificity of courier services has become very attractive not only for many trading, manufacturing enterprises but also for individual clients. Moreover, the global trends should be considered, such as the higher popularity of e-commerce, development of small and medium enterprises, higher activity of exporters provide for the further growth of CEP market, increasing competition among operators and higher demands of clients (Marczuk et al., 2015). To face these challenges and remain on the competitive market, courier enterprises must focus on the improvement of service as one of the key strategic aims. Therefore, the subject of measuring service quality in a courier branch is important and presents an issue both for practitioners and researchers. As far as scientific research is concerned, the current trend over the last years is the relatedness between quality management and services (Olszewska, 2016). Among many aspects of quality management, the authors have conducted research to find and develop models and methods for measuring quality in the field of service (Urban, 2013). Considering the quality measurement, an interesting problem that was outlined by Franceschini et al. but remains unsolved by researchers, is the aging of quality indicators caused among other things by changing demands of service customers (Franceschini et al., 2000).

The purpose of the paper is a critical analysis of literature concerning the evaluation of courier service quality and verification, provided criteria that determine the courier service quality change in time in the perspective of the next 5–10 years. The first section includes the overview of the research achievement concerning the issue of measuring courier service especially the measurement methods and criteria of courier quality assessment. The second one is dedicated to the description of author's own pilot research concerning the present and future expectations of clients using courier service. Finally, the conclusions of the examination and future research implications are presented.

1. Literature review

This section presents the critical literature review indicating the academic achievements in the field of courier service quality especially measuring methods and criteria of courier quality assessment aiming to systematize the knowledge and indicate possible research gaps. Unlike the academic output concerning the measurement of logistics service quality, there are only a few articles concerning the measurement of courier service quality in the world-wide literature (Gulc, 2016). Zhang et al. deliberate the method of courier quality service improvement called a Two-Stage Quality Functional Deployment (QFD). The method is based on Parasurman, Zeithaml, Berry's model (PZB model), QFD and the fuzzy set theory. The aim of the method is to transform express service demand into the express service resources. The authors outline that this method in not only available to analyse the whole express industry but also can be adopted by the whole service sector. Although, first and second stage of the QFD research can effectively reduce and even eliminate the negatively influencing factors in service of internal enterprise, namely the gap 1–4 in the PZB model, it does not verify the fifth gap measuring the difference between the perceived and experienced service quality (Zhang et al., 2012).

The study of Liu and Liu investigates the express logistics service quality in Changdao County in China by scales developed according to SERVQUAL method and LSQ theoretical models. The service quality scale was based on five dimensions, including reliability, protection, security (assurance), empathy, and perception (tangibles). The questionnaire containing 25 items was formed considering specific demands for the shipping express service in the island county. The research sample was 300 questionnaires, but only 199 were valid. The author does not specify if the respondents were only individual or also companies. The results of the empirical research show that the expected values of customers are significantly different from the perceived ones, showing that customers are not satisfied with the service quality of express logistics providers in Changdao. The results have shown that the dimension of security (assurance) achieved the highest rate while protection received the lowest. The authors recommend that the scale developed in this study may need further testing. Moreover, the sample in this study was drawn from Changdao County; thus, the conclusions inferred may not be generalized to other regions (Liu & Liu, 2014).

The paper of Ho et al. presents the application of the Logistic Service Quality (LSQ) model to determine the most important dimensions of client satisfaction from courier service. The model included the following variables: timeliness, condition/accuracy of

order, quality of information, and availability/quality of personnel. A multiple regression analysis indicated that not timeliness but condition/accuracy of order was the strongest factor influencing customer satisfaction with courier service. However, due to the increasing expectation from customers, timeliness was perceived as an entry-level requirement for every company in the logistic industry. The quality of information was also found to have a strong influence on customer satisfaction, while availability/quality of personnel was not a significant factor. The research based on snowball sample of 200 individual respondents mainly students limits the generalizability of this study. Sampling respondents from various groups including working adults and business organisations might provide a different scope of service quality expectations among logistic service providers (Ho et al., 2012).

In Polish literature, there are only a few papers concerning courier service quality. Dyczkowska's paper presents two groups of customers – individual and institutional, who buy transport–forwarding–logistics service (TFL) including courier service. The paper presented conditions decided about the choice of logistics operator and how customers assessed courier service quality and their satisfaction. The most popular criteria of services selection in TFL sphere both by the individual and institutional customer were a time of delivery, service quality, and price. The paper considered the specificity of courier service, but it did not specify the part of the supply chain of TFL service that was the subject of research. Moreover, the research sample was limited only to 30 individual clients and 45 institutional ones without distinction of their size. The author did not explain how the service quality should be understood by respondents. The research results could be confusing because apart from the service quality there were other separate criteria being rather the features of service quality for example timeliness, completeness of delivery, a small number of compliments (Dyczkowska, 2011).

Ratajczak and Lorenc analysed the data concerning the time of delivery in one local courier company in Poland, *X-press Couriers*. The data showed that the level of timeliness was very differentiated. The authors also analysed the reasons for client complaints indicating the timeliness, breakage, and loss of delivery. The research has the fragmentary character; it concerns one single company and presents only one aspect of the service quality, i.e. timeliness (Ratajczak & Lorenc, 2015).

The research of Frąś was based on the SERVQUAL method. It was conducted in 2009 and 2012, on a sample of 400 respondents who were clients of courier service, but only 225 surveys were completed. The research was conducted by examining the expectations concerning the quality of courier service, as well as assessment of already experienced courier service. The perceived service measured as the difference of experienced and expected quality was assessed on the account of five service criteria: reliability (the ability to perform the promised service dependably and accurately), assurance (the knowledge and courtesy of employees and their ability to convey trust and confidence), tangibility (the appearance of physical facilities, equipment, personnel and materials), empathy (caring, individualized attention to customers) and responsiveness (the willingness to help customers and to provide prompt service). The lowest rated criterion was the third one – responsiveness, and the highest rated one was the first criterion – tangibility. It should be noted that compared to the results of the survey in 2009, the service quality improved slightly in 2012. The author did not characterize the research sample or explain if the questions in the survey were adopted into the specificity of courier service (Frąś, 2014).

The paper by Rutkowski et al. is a complex study on the conditions of courier service development, the role of courier service in the Polish economy and future trends of this branch. The paper includes the results of the survey, which aimed to present the role of courier service in creating the competitiveness of Polish companies. 81 companies, which took part in the survey had to choose the factors that determine the choice of courier service. The results showed that 98% of small and medium enterprises and 94% of large companies admitted that next-day delivery is the most important factor in choosing the courier service as well as the same-day delivery and delivery tracking. 76% of small and medium enterprises and 55% of large companies said that without the access to courier service, their international activity would be very limited. Although the research results are interesting, it would be reasonable to verify them with an extended research sample (Rutkowski et al., 2011).

The paper by Dmowski et al. concerns the evaluation of service in two courier companies from the perspective of 60 customers, mainly small companies. The research focused on a few operation areas of chosen courier enterprises, which are essential from the point of view of contractor needs. These were:

Tab. 1. Overview of criteria for measuring courier service quality

QUALITY CRITERIA	AUTHOR						
	A	B	C	D	E	F	G
Timeliness	■	■	■	■			■
Condition/accuracy of order	■	■		■			
Quality of information	■						
Availability/quality of personnel	■	■	■				
Reasonable and Formal Charges		■		■			
Client service		■	■				
Communication with clients			■				
Willingness and commitment to the search for solutions to problems/Empathy			■	■	■	■	
Lack of delivery damage				■			
Small number of compliments				■			
Service quality				■			
Complexity of proposal				■			
Reliability			■	■	■	■	
Responsiveness			■	■	■	■	
Assurance					■	■	
Tangibility					■	■	

Source: author's elaboration on the basis of (A – Ho et al., 2012; B – Zhang et al. 2012; C – Dmowski et al., 2013; D – Frąś, 2014; F – Liu & Liu, 2014; G – Ratajczak & Lorenc, 2015).

knowledge and competence of staff, customer service level, time of response and courier service, communication between courier companies and clients, the willingness and commitment to the search for solutions to problems. In every case, the client (company) made the assessment of the significance of the criterion on a scale of values from "very low", to "average" and "very high". The research results have shown that the high overall assessment of the quality of the service provided by one of the two courier companies was caused by the highly-rated level of knowledge and competence of employees, fast response time for complex orders, and commitment of the employees in solving current problems of customers. The information collected in the study clearly proved that cooperation with the client, which means a high level of customer service, is an essential criterion for choice and continuous cooperation with couriers, and, thus, an essential part of building a competitive advantage (Dmowski et al., 2013).

Summing up, although the express branch has developed rapidly and the courier service quality is one of the key goals for courier operators on the competitive market, the overview of literature has shown that only a few authors focus their research interests on this aspect both in Poland and worldwide. Moreover, researchers have not still deliberated one universal set of criteria to assess courier service quality and each author proposed a different point of view. As Table 1 shows, some of them used general criteria based on the SERVQUAL method (E–F) while others propose more detailed ones (A–D). All proposed criteria do not consider changing demands of clients and current facilities offered by courier operators. Moreover, some studies focus on one group of respondents for example institutional clients (Rutkowski et al., 2011; Dmowski et al., 2013) or individual ones (Ho et al., 2012), while others compare both individual and institutional client evaluation (Dyczkowska, 2005). Moreover, in some cases, the research sample is not specified, or authors do not pay attention to characterizing the research sample (Frąś, 2014; Zhang et al., 2012; Liu & Liu, 2014). As far as assessment methods of service quality are concerned, some researchers use the full version of the SERVQUAL method assessing the perceived and expected quality (Frąś, 2014; Zhang et al., 2012) while others examine only expectations of clients or experienced service quality (Dyczkowska, 2005; Dmowski et al., 2013; Rutkowski et al., 2011; Ho et al., 2012; Ratajczak & Lorenc, 2015).

Based on the literature overview, some research gaps can be mentioned: the lack of a clearly defined evaluation constructs of courier service quality

together with the criteria for their evaluation and weight, the lack of a commonly used measuring scale for the evaluation of the service quality, the lack of diversification of methods and measurement tools for various groups of stakeholders (service provider, service recipient – an individual and an institution). Moreover, it can be concluded that the research concerning the courier service quality have not considered the problem of the aging of quality indicators, which was outlined by Franceschini (Franceschini et al., 2000).

2. Research methods

In response to the identified research gap concerning the problem of the aging of quality indicators, the aim of the pilot research was to verify if criteria that determine the courier service quality change in time. The research was based on the Internet surveying technique CAWI. The survey was addressed to clients of courier service, both individuals and enterprises located in Poland. The main question in the questionnaire was to rate the features of courier service that were essential in choosing the service today and ascertain their importance in the next 5–10 years. The respondents had to rate the courier service according to the seven-point Likert scale with anchors ranging from "the least essential" to "the most essential". The data was collected from 30 May 2016 to 7 August 2016. Based on the literature overview and web-sites of courier companies, thirteen criteria of service quality were elaborated:

- time of delivery (1);
- service price (2);
- service availability and information (the availability of information about the company and the proposal, fixed working hours, the location of the collection points, ease of contact, etc.) (3);
- flexibility to handle the delivery in terms of time and place (4);
- ability to take advantage of additional service (notification of receipt by text message or email, charges on delivery, written proof of delivery, etc.) (5);
- comprehensive service – the ability to use the accompanying services (receipt of the waste, packaging, package pick-up, full logistics service, etc.) (6);
- service individualization (proposal matching to the needs of a specific client or industry) (7);
- modern technology (individual PUDO – PickUp DropOff point near houses or apartments instead of boxes, drones or robots as couriers, etc.) (8);
- tele-technologies (ICT, mobile apps, the ability to manage shipment tracking, the ability to generate reports, constant contact with the client, etc.) (9); modern packaging solutions (the variety of packaging, packaging availability, possibility of packaging by courier, the aesthetics of packaging, packaging customization, etc.) (10);
- competence and qualifications of the service provider (professionalism and preparation of the service provider, the knowledge, skills, etc.) (11);
- staff politeness (12);
- trust (the credibility and reliability of the company, honesty, etc.) (13), (Kawa, 2014; Liu & Liu 2014; Dyczkowska, 2005; Anioł, 2015; Biznes raport… 2015; Frąś, 2014).

The research sample consisted of 231 respondents; however three of them were not the customers of courier service, so finally, 228 questionnaires were completed. Respondents of this study were 60% females and 40% males. Considering the age of respondents, the most active group of courier service clients was the one of the age from 18 to 55 years old, the least (0%) – below 18 years of age (Fig. 1).

As far as the level of education is concerned, the majority of clients using courier service were those with a Master degree (64%) while the minority – those with the primary level of education.

Over a half of all respondents use courier service often, i.e. once a month (31%) and more than once a month (29%), while the minority (a quarter) of customers use the service less than once per quarter (Fig. 3).

In this pilot research, most of the respondents were individuals (73%); however, 28% were enterprises. Surprisingly, 12% of enterprises were large, hiring over 250 employees (Fig. 4).

3. Research results and discussion

The respondents had to assess the significance of thirteen criteria, which determine the choice of courier service at present and in the future (in 5–10 years). The collected answers were analysed statistically. Firstly, the average assessment of each criterion of courier service was calculated considering the

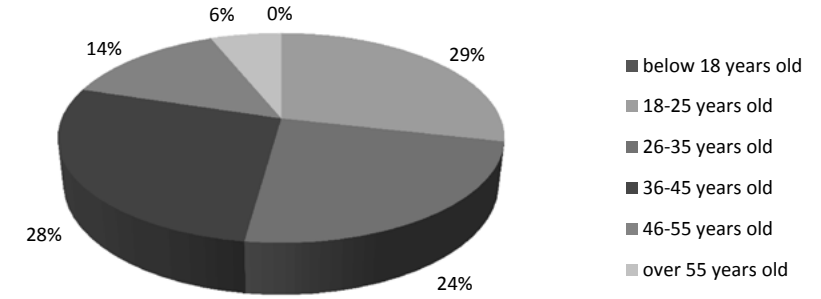

Fig. 1. Age of respondents [%]

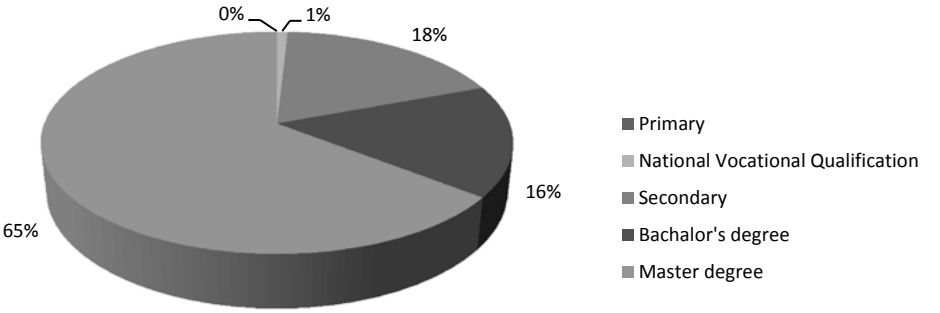

Fig. 2. Education level of respondents [%]

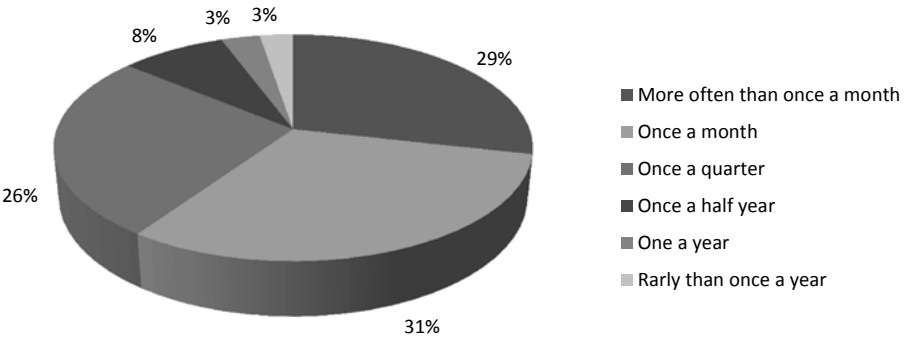

Fig. 3. Frequency of courier service use [%]

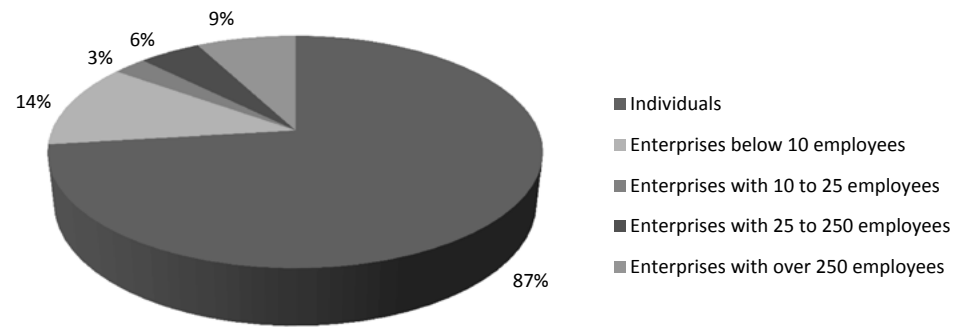

Fig. 4. Groups of respondents [%]

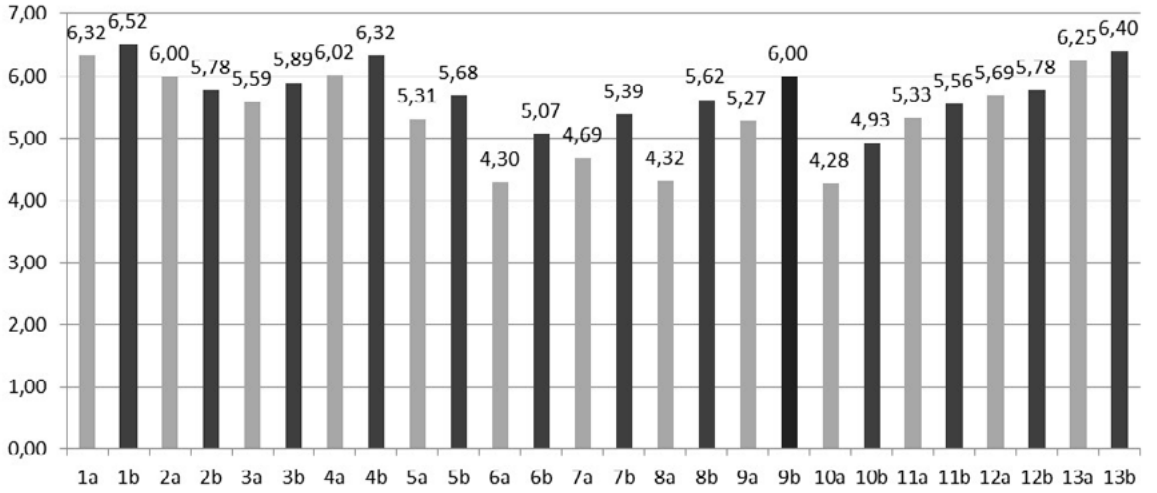

Fig. 5. Assessment of courier service quality at present (a) and in future (b)

present (a) and future assessment (b), (Fig. 5.). The obtained results were checked using the Wilcoxon signed-rank test – a non-parametric statistical hypothesis test used to compare two related samples. The differences between the two matched samples (b–a) were statistically significant ($p<0.005$ in each case). Considering the assessment of the present service, the highly rated are a time of delivery (1a), trust (13a), flexibility (4a), and price (2a), while the least ones were comprehensive service (6a), modern technology (8a), and modern packaging solutions (10a). Similarly to other research, these results proved that one of the most important criteria for clients was a time of delivery and price but surprisingly also trust – reliability and honesty of courier enterprise as well as delivery flexibility, which is especially important for individual clients nowadays (Biznes raport…, 2015). As far as the future client demands are concerned, all of the criteria were assessed higher than at present, except for the price, the importance of which should decrease in future. In the perspective of 5–10 years, clients assessed that the most important criteria for them will be not a time of delivery (1b), trust (13b) and flexibility (4b) alone, as previous research showed, but also tele-technologies (9b).

Showing the difference between the significance of criteria in the future and nowadays (b–a), respondents think that the most rapid development would be seen in the importance of modern technologies, such as drones or individual pick-up & delivery boxes, but also comprehensive service, service individualization, tele-technologies, and modern packaging solutions, which nowadays are not as important. In the case of time of delivery, staff politeness and trust, their increase in significance will be the lowest. The Fig. 6 also presents that the price will be a less important criterion for clients in the future than nowadays. Based on these results, it can be assumed that customers will not only pay attention to price or a time of delivery while choosing courier service but will also look for new technological solutions that will provide them comfort and individualised treatment.

The data presented in Table 2 indicates the percentage of respondent answers showing the difference between the future (b) and present expectations (a).

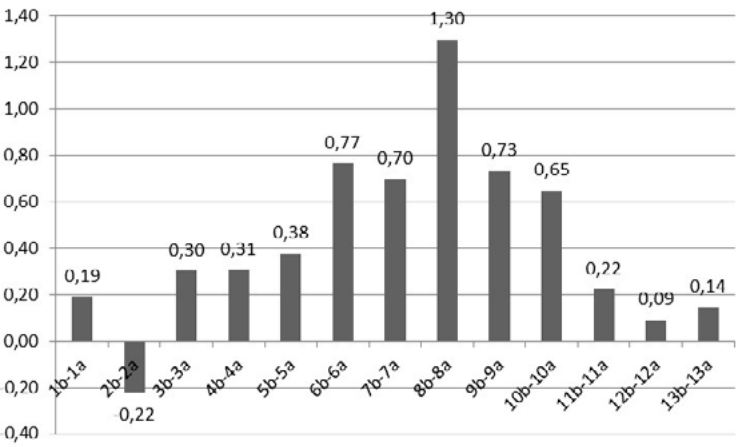

Fig. 6. Difference between the importance of criteria at present and in the future

Tab. 2. Difference between significance of criteria today and in the future

Difference b-a \ Criteria	1	2	3	4	5	6	7	8	9	10	11	12	13
6	0%	0%	0%	0%	0%	1%	0%	2%	2%	0%	1%	0%	0%
5	0%	0%	1%	2%	0%	0%	0%	3%	3%	0%	0%	0%	0%
4	2%	1%	0%	2%	1%	5%	5%	7%	7%	5%	3%	0%	0%
3	5%	0%	6%	6%	8%	13%	11%	19%	19%	10%	11%	8%	4%
2	17%	11%	12%	27%	33%	33%	35%	41%	41%	38%	31%	18%	42%
1	63%	29%	67%	55%	44%	44%	46%	28%	28%	42%	48%	65%	54%
-1	7%	25%	9%	5%	10%	5%	4%	66%	1%	5%	7%	8%	4%
-2	2%	25%	4%	0%	4%	2%	1%	1%	1%	4%	3%	4%	4%
-3	5%	7%	5%	6%	4%	1%	0%	1%	0%	0%	0%	2%	4%
-4	5%	4%	0%	2%	0%	0%	1%	0%	0%	0%	0%	0%	0%
-5	0%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

The difference between these two assessments (b–a) is presented in the range <-6;6>. The greatest share of respondents pointed out the difference of importance at the level of 1 point: more than 50% of respondents chose this assessment for a time of delivery, service availability and information flexibility, staff politeness and trust (dark grey boxes). However, there were some deviations in responses at the level of 2 points and the greatest number of respondents was noted in the case of criteria 2 and 4–11 (grey boxes). Moreover, there were also the differences at the level of 3 points as the greatest number of respondents was observed in the case of criteria 6–11 (light grey boxes). The results proved that client expectations change in time, and in the case of some criteria, the difference between the present and future expectations is significant.

Moreover, the last question in the questionnaire was open and concerned other, unmentioned features of service that could be important for clients in the future. Apart from many similar criteria used in the prepared questionnaire, some respondents suggested interesting and new solutions in courier service for example:

- freely contacting the courier;
- cheap shipments from the place of client's residence;
- a greater flexibility of working hours of couriers;
- ability to redirect a shipment dynamically during the service from one option to another place, for example, change your delivery address to a different one or PUDO or another pick-up point;
- ability to return the ordered product directly to the courier;
- diversification of courier service, i.e. the development of forms food/laundry delivery as a form of click & collect.

These propositions suggest that clients have constantly increasing expectations as well as they can be the source of inspiration and innovative ideas concerning courier service. Moreover, the knowledge about changing expectations of clients allow adjusting courier proposals to customer needs to gain a competitive advantage in the global market.

Conclusions

Considering current trends in the CEP market and the academic output concerning courier service, it can be concluded that the aspect of measuring the courier service quality is still a relevant part of management science and needs further research. The critical overview of literature has revealed that authors use different criteria and scales to measure the courier service quality. Moreover, the measuring criteria are not based on the current technical and technological achievements used by courier enterprises. The research is usually based on the same or slightly changed method despite the variety of measurement tools and methods available in service science. Moreover, it can be stated that the research in the courier service quality have not considered the problem of the aging of quality indicators. The results of author's pilot research have proved that client expectations change in time. Although the differences between the assessment of courier service quality

at present and in the future are not very significant, the results show the future trends among courier service. Similarly to other research, the results have proved that nowadays one of the most important criteria for clients is a time of delivery and price, but surprisingly also trust and delivery flexibility (Biznes raport…, 2015). In the perspective of the next 5–10 years, the expectations of clients will increase in the case of all criteria, except for the price, the importance of which will decrease. In the future, clients believe that the most important criteria for them will be not a time of delivery, trust and flexibility alone as previous research suggested, but also tele-technologies. In the future, clients will choose a service that will be fast and comfortable. This is the reason to be interested in modern technical improvements, such as drones or individual pick-up & delivery boxes, but also comprehensive service, service individualization, tele-technologies, and modern packaging solutions, which are not considered as important nowadays. The results of this research can be useful for courier enterprises to recognize future client expectations, but also to check if new solutions would be accepted by customers. Clients can also be the source of inspiration and innovative ideas concerning courier service. For further research, it is recommended to determine a universal set of criteria and measuring scale dedicated to courier service as well as conduct a broader research on future expectations of clients.

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Concept of uncertainty in relation to the foresight research

Andrzej Magruk

ABSTRACT
Uncertainty is one of the most important features of many areas of social and economic life, especially in the forward-looking context. On the one hand, the degree of uncertainty is associated with the objective essence of randomness of the phenomenon, and on the other, with the subjective perspective of a man. Future-oriented perception of human activities is laden with an incomplete specificity of the analysed phenomena, their volatility, and lack of continuity. A man is unable to determine, with complete certainty, the further course of these phenomena. According to the author of this article, in order to significantly reduce the uncertainty while making strategic decisions in a complex environment, we should focus our actions on the future through systemic research of foresight. This article attempts to answer the following research questions: 1) What is the relationship between foresight studies in the system perspective to studies of the uncertainty? 2) What classes of foresight methods enable the research of uncertainty in the process of system inquiry of the future? This study conducted deductive reasoning based on the results of the analysis methods and criticism of literature.

KEY WORDS
uncertainty, foresight, future, system, determinism

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Introduction

In all spheres of human activity, uncertainty plays a special role. In the economic context, it is recognized as one of the major global megatrends alongside such phenomena as circular economy & sustainability, regional empowerment, collaborative crowd economy, and volatility (Bubner et al., 2014). Uncertainty is inherent in any decision. This is because the essential feature of the decision-making process is the orientation towards the future, which is inherently uncertain (Dziel, 2011).

The high pace of change in the social, economic, and technological areas and high complexity of the today's world functioning led to an increasing need to manage these changes and the accompanying uncertainty to create wealth and enhance the quality of life

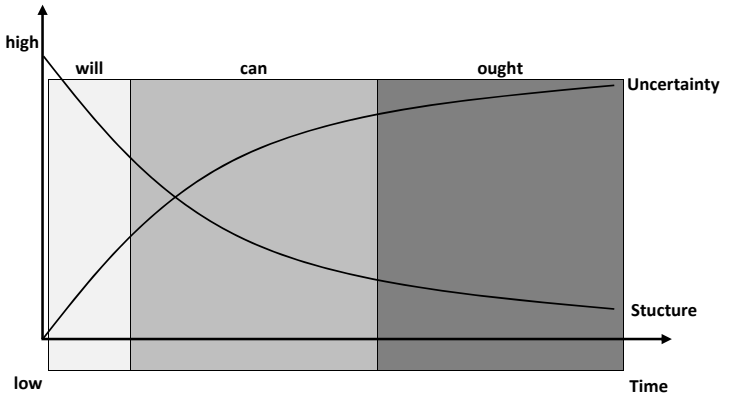


Fig. 1. Structure and uncertainty relationship

Source: (Saritas & Oner, 2004 redrawn from Graf, 1999).

by taking the relevant decisions (Saritas & Oner, 2004).

In our daily lives, some answers to some problems are so simple that we are not even aware of their making and execution. However, extending of the time horizon increases the feeling of uncertainty regarding the ability to make based on known patterns. The number of components of the problem increases by getting lower awareness of the types and characteristics of the components of these problems (Fig. 1), (Saritas & Oner, 2004).

If a decision problem is more complex, it is more difficult to recognize its essence and take appropriate action. It is impossible to specify both the effects, circumstances and conditions, in which these activities are exercised. There are situations where it is impossible to predict what consequences will be decided. Such situations are situations of uncertainty. It is impossible to predict the consequences, but it is possible to anticipate different variants of these effects (Łuczak, 2012). According to the author of this article, the methodology of systemic research of foresight is one of the major approaches that allow this action. It is also one of the most powerful tools that help to build a clear "cone of future possibilities" by minimizing the uncertainty effect.

Each systemic object can be treated as a huge, multi-level structure. The study of such systems always contains a barrier of the uncertainty resulting from the barriers of unawareness about the system. The source of this ignorance may be either the incomplete information available on the audited system or limited cognitive abilities of a researcher. It is not possible to eliminate this barrier (Bojarski, 1981).

This article attempts to answer the following research questions: 1) What is the relationship between foresight studies in the system perspective to studies of the uncertainty? 2) What classes of foresight methods enable the research of uncertainty in the process of system inquiry of the future? This study conducted deductive reasoning based on the results of the analysis methods and criticism of literature.

1. Concept of the system and the determinism towards the phenomenon of uncertainty

According to Skolimowski, nature has been written in the language of the entirety. The wholeness is not only a term used to describe the relationship between the parts but is also an epistemological category: the total and holistic thinking are ways to understanding all aspects of starting from a single man and ending with the universe. We live in an open non-deterministic world. We should realize that the world is ruled by a variety of subtle dependencies that have nothing to do with the determinism understood in the positivist way (Błajet, 2011).

At the beginning of the nineteenth century, Pierre Simon, Marquis de Laplace, under the influence of successful scientific theories, put a bold but as it turned out – after about a hundred years – irrelevant hypothesis that the universe is completely determined. According to this approach, knowing the exact state of all phenomena in a given moment, a man could predict the exact state of this phenomena in the future, including human behaviour. Laplace's doctrine remained the classical assumption in science until the early years of the twentieth century. A milestone in breaking this position was the indeterminacy (uncertainty) principle in quantum physics formulated by Heisenberg in 1926. This principle, using largely the assumptions of probability, is considered to be a fundamental property of the world inevitable. The indeterminacy principle, resulting from the uncertainty of measurement, introduced to the science the attitude of paying attention to the phenomena of randomness and unpredictability. This means that it is not really possible to accurately predict future events if we are not able to determine, with

sufficient precision, the current state of the universe (Hawking, 1990). The theory of heat was another important theory that came from the field of statistical mechanics, preceding the indeterminacy principle (the last decades of the nineteenth century), which began to follow the scientific thinking towards indeterminism. One of the most important scientists working on this topic was Maxwell. He used the concept of singularities referred to as small disturbances of occasion causing large disturbances in the effects (Heller, 2016b).

Indeterminacy compounds define the limit, beyond which it is impossible to move the concepts of classical physics. Similarly, it can be said that the level of complexity (and, thus, also the uncertainty) of the system marks the boundary, beyond which it is impossible to examine the system following the principles of deterministic relationships.

In the early 60s of the twentieth century, Zieleniewski pointed out that the study of whole states cannot accurately observe all the characteristics of the elements of the structure and at the same time changes in this structure. This brings up the principle of indeterminacy of large dynamic systems. It involves the inability to freely and accurately determine, in any narrow range of time, all states of elements and their relationships in a big system in the past, and even more so in the future. Perforce, therefore, abstract static tests of selected attributes and their relations are used or dynamic tests of changes some few traits without the other (Bojarski, 1981). This can be used, for example, in the principle of economy known as Ockham's razor, by removing from the theory everything that cannot be observed (Fatyga, 2015).

The uncertainty in the context of the analysed system may include (Fig. 2), (Bojarski, 1981):

- one or more parameters of the system;
- the equation of state or system motion;
- the structure of the system;
- the internal and external scope of the system;
- the desirability of preserving the system.

For further horizons, uncertainty continues to expand and deepen. This is due to, among other things, the complexity of the features, structures, and behaviours of systems, which usually extends beyond the area observed and verified by available knowledge, especially for individuals. On the occurrence of uncertainty in the context of a forward-looking analysis of the complex systems development affect the following factors (Bojarski, 1981):

- a multitude of possible system structures, their high complexity, and variability over time;
- the number and strength of connections inside the system;
- the number and degree of knowledge of the system's relations with the environment, and insufficient knowledge of the environment;
- the scope of structural changes;
- behaviour of individuals and institutions managing system test in the context of the potential going beyond the known rules and regulations;
- ignorance of potential new rules and principles and their scope;
- an increasing number of possible combinations of events occurring in the studied systems;
- the length of the considered time horizon;
- the lack of sufficiently complete data.

Uncertainty next to the complexity of the studied phenomena (systems) creates a space, in which one can determine the boundaries of computability (Fig. 3).

Despite the fact that knowledge is the lifeblood of developing and developed economies (Olszewska & Gudanowska, 2011), live systems, the climate, and the economy still require for fields to experiment and statement claims demand for necessary but uncertain prove (Cempel, 2005).

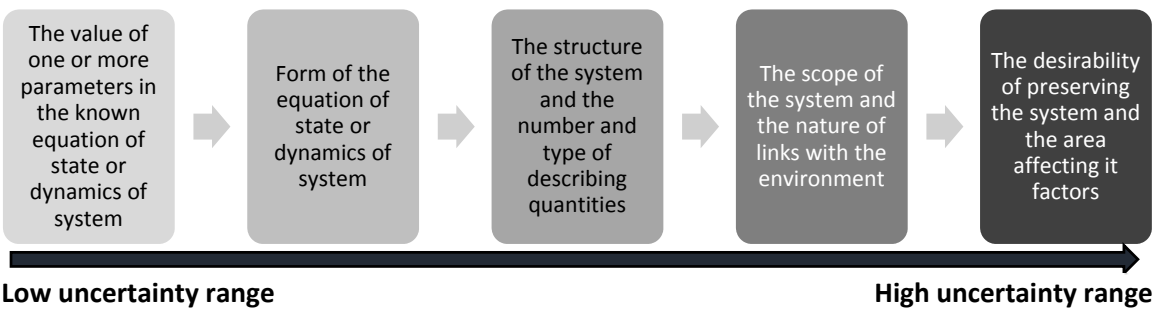


Fig. 2. Level of the scope and significance of uncertainty in the context of the system

Source: own elaborations on the basis of (Bojarski, 1981).

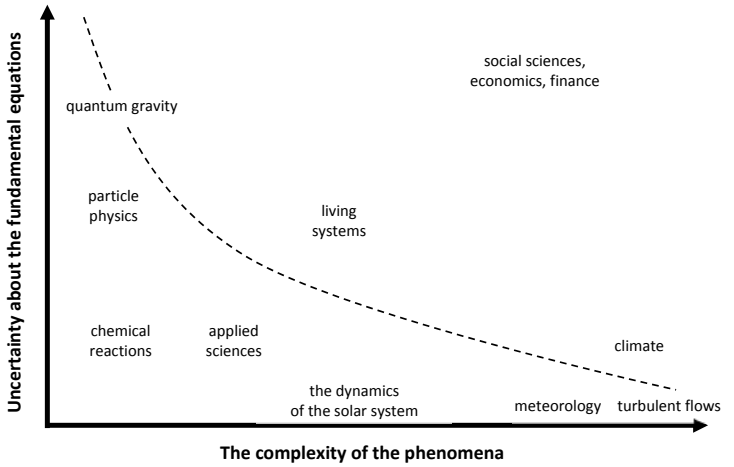


Fig. 3. Uncertainty and complexity as the boundaries of our knowledge
Source: (Cempel, 2005).

2. Foresight research in relation to the concept of uncertainty

Expert (intuitive) research approaches can be used to determine the vision of the development of phenomena in time significantly exceeding the maximum horizon of typical forecasts (based on deterministic models), (Halicka, 2016; Halicka, 2014). One such tool is the methodology of foresight, based on the collective expertise anticipation of complex phenomena.

Especially complex foresight studies try to predict the uncertain future affected by many factors. In terms of the nature of the foresight process, uncertainties should always be taken into account (in addition to the complexity and conflictuality of nature). Incorrectly defined and unstructured problems reflect the higher dynamic complexity, and thus uncertainty. Foresight should be used to anticipate an uncertain future taking into account the numerous factors and complex structural and behavioural dependence (Saritas & Oner, 2004).

Foresight is exploring the future through its impact on the present. So, we have to deal with the practical application of the reversal arrow of time, a well-known phenomenon in quantum physics (Błajet, 2011). Intuitively, future studies can consider only psychological variation of the arrow of time. It is linked to the human sense of the passage of time, the fact that we remember the past and not the future (Hawking, 1990). In the case of perception reversal, as may be in the foresight case, "we can remember" events from the future and try to play all the situations that preceded it, in the anti-chronological order. Thanks to this approach, it seems to be an easier implementation of one of the paramount roles of foresight – not foreseeing but understanding the future (Gudanowska, 2016) by creating it (Gudanowska, 2014).

In the process of inquiry into the future, there are two types of conditions on the anticipation and decision-making. Referring to the researches by Willett, these are the conditions of objective risks (mathematically quantifiable) and subjectively interpreted uncertainty (Janasz, 2009).

The conditions of risk exist when our every action leads to one outcome of a particular set of possible outcomes. Terms of uncertainty occurring then if one or both actions are a result of a set of defined possible outcomes (the set is not fully defined, we know some alternatives results but not all), but the probability of occurrence of these results is totally unknown or impossible to know (Fig. 4), (Samecki, 1967).

Uncertainty in foresight research is rather the background of its research and not its main subject. However, there are several methodological areas of foresight, in which the problem of uncertainty is the object of research, i.e.:

- scenario analysis;
- future cone;
- cone of uncertainty;
- strategic foresight.

The result of foresight research is usually a space of possible scenarios, which, according to Ringland may be defined as part of strategic actions, which relates to the tools and technologies for managing the uncertainties of the future (Ringland, 1998).

Mietzner and Reger claim that scenario planning allows us to understand the degree of uncertainty and its importance while scenario building means speculating about the future uncertainty (Kononiuk & Nazarko, 2014).

Referring to research by Kononiuk and Nazarko, based on the concepts of Amara and Bazolda (Kononiuk & Nazarko, 2014) and studies of Voros (Voros, 2003), probable, plausible, possible, preferable and desirable scenarios can be distinguished (Fig. 5).

The expanding cone shows the complexity and uncertainty of the future. This is because the farther

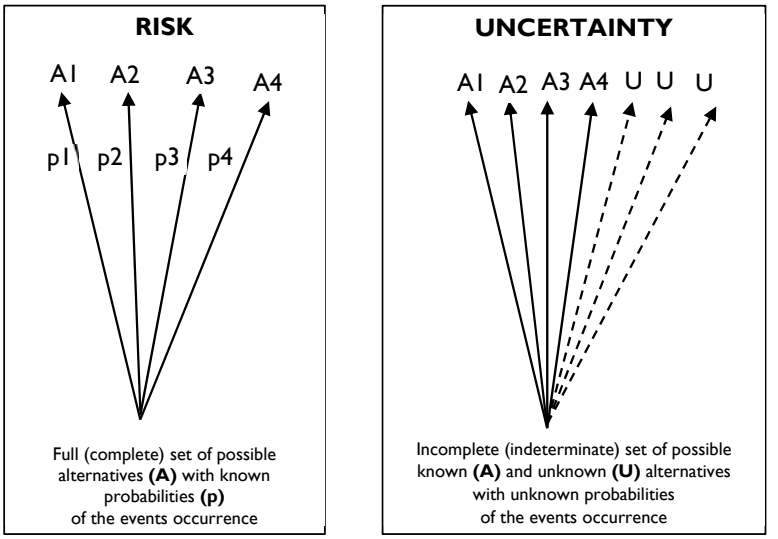


Fig. 4. Conditions of risk and uncertainty

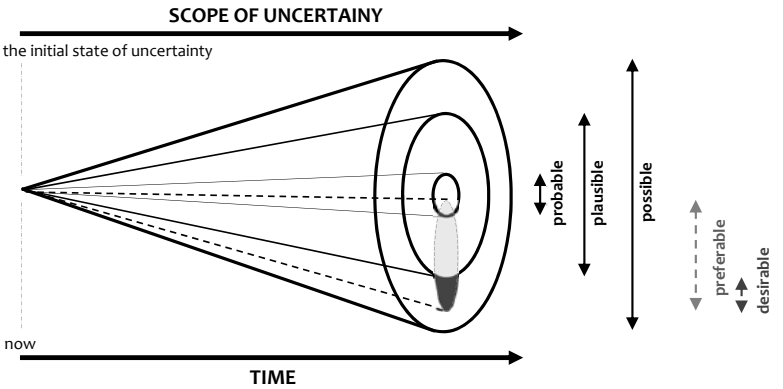


Fig. 5. Cone of future

Source: own elaborations on the basis of (Kononiuk & Nazarko, 2014; Voros, 2003).

we run out into the future, the further increases the scope of uncertainty. At the same time, increases the rate of change in the structure of the observed system (Błajet, 2011).

Another important area of future studies in the field of uncertainty is the cone of uncertainty and possibilities (Fig. 6). The archetype of these analyses in the form of a light cone of the future and the past is in space-time research within the framework of special and general relativity theory (Hawking, 1990; Heller, 2016a).

Referring to studies by Hawking, the absolute future event P is inside the cone of the future. It is a collection of all events, which can affect what happens in P. The absolute past events P is a region within the cone of the past. It is a collection of all these events, for which the information could get to P. Hence, the absolute past P is the set of all events that could have an impact on what happened in P. In the completely deterministic system,

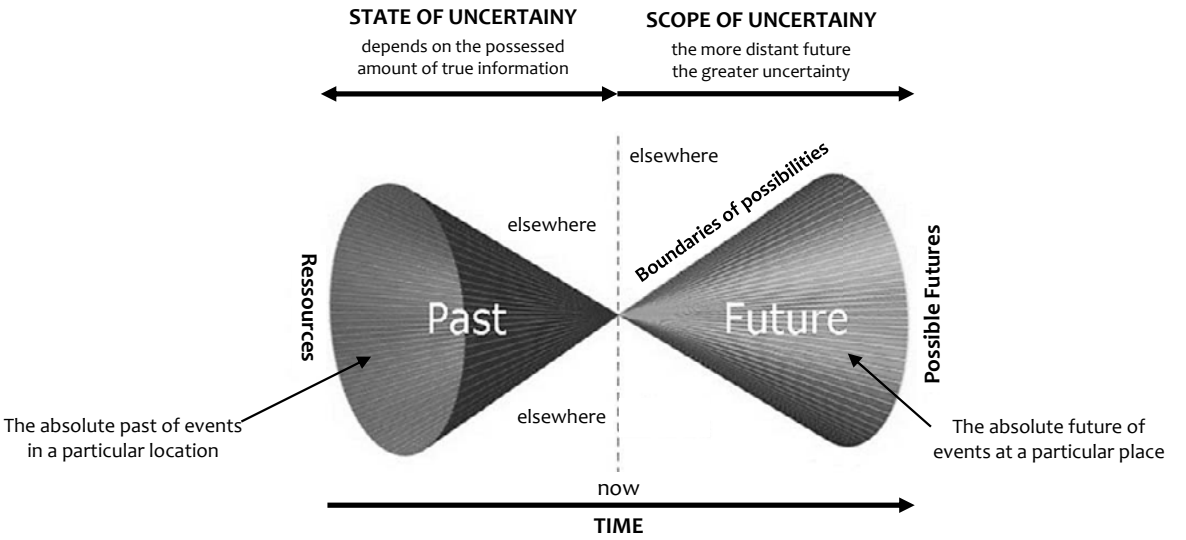


Fig. 6. Cone of uncertainty and possibilities

Source: own elaboration on the basis of (Hawking, 1990; Magnus, 2012).

if it would be known what was happening at a specific time at all points of the space area situated within the cone of the past, it could be a possibility to predict with a high probability, what will happen in the P (in indeterministic systems, past and present events determine only distribution probabilities of possible states in the future (Heller, 2016b). "Elsewhere" is the part of the space lying outside the two cones of events P. The events in the "elsewhere" cannot affect the P or the P incident cannot affect them (Hawking, 1990).

According to Magnus, the cone of uncertainty and possibilities is a model of all development roads in the future. It is conditioned by the resources of knowledge and information from past and present. More probable future's paths are closer to the centre, and unrealistic paths (by increasing the extent possible, while high uncertainty) are located on the outskirts of the cones (Magnus, 2012).

Residual uncertainty is characteristic of strategic foresight and is defined by Courtney as the uncertainty left after the best possible analysis to separate the unknown from the unknowable. The residual uncertainty always takes only one of four levels (Table. 1), (Courtney et al., 1997; Courtney, 2001):

- Level 1: A Clear-Enough Future;
- Level 2: Alternate Futures;
- Level 3: A Range of Futures;
- Level 4: True Ambiguity.

Another complementary approach is presented by Jańczuk. It distinguishes three types of uncertainty in the context of foresight: simple uncertainty (which is the difference between certainty and reliability in terms of risk), accumulated (uncertainty in the strict sense) and independent uncertainty (unprecedented). Independent uncertainty refers to abnormalities that represent a total surprise to the observer. Knowledge of these phenomena appears simultaneously with the occurrence of it (Jańczuk, 2007).

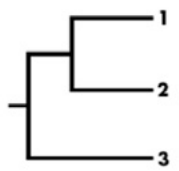
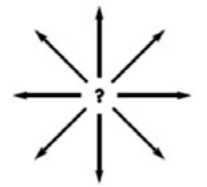
3. Classes of foresight methods influencing the process of uncertainty research

Because in the predictive considerations, one of the main aims is to minimize any uncertainties associated with predictions, the question is: "What foresight methods affect the identification and analysis as well as minimize the effects of uncertainty?". Due to the limited capacity of the article, the Tab. 2 below shows the answer in the accumulated form, based on the research relating to classes of foresight methods. Detailed description of the classes and methods belonging to them (Table 2) is provided by (Magruk, 2011).

Based on the analysis of the characteristics of individual foresight research methods and the author's experience resulting from active participation in several foresight initiatives, the total assessment of the relationship of classes of methods was made for testing the uncertainty in 3 aspects: identification, analysis and minimization (Table 3).

The first class is a consultative group of methods based on the study of expert opinion. This is particularly important in the case of complex issues where there is a high uncertainty regarding the interpretation of the data in the forward-looking context. Thanks to the methods of this cluster, it is possible to collect tacit knowledge, inaccessible in traditional

Tab. 1. Four levels of residual uncertainty

	Level 1	Level 2	Level 3	Level 4
Graph				
Definition	Can be developed a single forecast of the future that is precise enough for strategy development	The future can be described as one of a few alternate outcomes, or discrete scenarios	Range of potential futures is defined by a limited number of key variables	Multiple dimensions of uncertainty interact to create an environment that is virtually impossible to predict
Example methods	market research, analyses of competitors' costs and capacity, value chain analysis, Porter's five-forces framework	decision analysis, option valuaion models, game theory	lantent-demand research, technology forecasting, scenario planning	analogies, pattern recognition, nonlinear dynamic models

Source: (Courtney et al., 1997; Courtney, 2001).

Tab. 2. Classification of foresight research methods

THE NAME OF CLASSES	FORESIGHT METHODS BELONGING TO EACH CLASS
Consultative	Voting, Polling, Survey, Interviews, Expert Panels, Essays, Conferences, Workshops, Citizen Panels, Brainstorming
Creative	Wild Cards, Weak Signals, Mindmapping, Lateral Thinking, Futures Wheel, Role Play, Business Wargaming, Synectics, Speculative Writing, Visualization, Metaphors, Assumption Reversal
Prescriptive	Relevance Trees, Morphological Analysis, Rich Pictures, Divergence Mapping, Coates and Jarratt, Future Mapping, Backcasting, SRI Matrix, Science Fiction Analysis, Incasting, Genius Forecasting, Futures Biographies, TRIZ, Future History, Alternative History
Multicriterial	Key Technologies, Source Data Analysis, Migration Anal., Shift-Share Anal., DEA, Factor Anal., Correspondence Anal., Cluster Analysis, Sensitivity Analysis, AHP, Input-Output Analysis, Priorization, SMART, PRIME, MCDM
Radar	Scientometrics, Webometrics, Patent Analysis, Bibliometrics, Technological Substitution, S-Curve Analysis Technology Mapping, Analogies
Simulation	Probability Trees, Trend Extrapolation, Long Wave Analysis, Indicators, Stochastic Forecast, Classification Trees, Modeling and Simulation, System Dynamics, Agent Modeling
Diagnostic	Object Simulation, Force Field Analysis, Word Diamond, SWOT, STEEPVL, Institutional Analysis, DEGEST, Trial&Error, Requirement Analysis, Theory of Constraint, Issue Management, ANKOT
Analytical	SOFI, Stakeholder Analysis, Cross-Impact Analysis, Trend Impact Analysis, Structural Analysis, Megatrend Analysis, Critical Influence Analysis, Technology Barometer, Cost-Benefit Analysis, Technology Scouting, Technology Watch, Sustainability Analysis, Environmental Scanning, Content Analysis, FMEA, Risk Analysis, Benchmarking
Survey	Web Research, Desk Research, Technology Assessment, Social Network Analysis, Literature Review, Retrospective Analysis, Macrohistory, Back-View Mirror Analysis
Strategic	Technology Roadmapping, Technology Positioning, Delphi, Scenarios, Social Impact Assessment, RPM, Technological Scanning, Multiple Perspectives Assessment, Causal Layered Analysis, MANOA, Action Learning

Source: (Magruk, 2011).

sources of information, by which identification and analysis of uncertainty areas are fuller, and minimization can be done in a manner based on the expert experience.

The second class has a strong connection with research of uncertainty. The methods of this group enable both synthetic and unconventional presentation of many issues with a single shot (in the form of a diagram, map, picture). These methods facilitate the discovery (using simulations, analogies) of seemingly unrelated relationship (interaction) between different objects, influencing the formation of entirely new ideas. The creative class allows the analysis and minimization of the effects of uncertainty in an unconventional (for instance avant-garde) way.

Using the prescriptive methods, it is possible to undertake identification, indexing and counting of solutions to the problem utterly from the point of view of present and future

Tab. 3. Linking classes of foresight methods with the research areas of uncertainty: the identification, analysis, and minimization

		RESEARCH OF UNCERTAINTY		
		IDENTYFICATION	ANALYSIS	MINIMALIZATION
CLASSES OF FORESIGHT METHODS	CONSULTATIVE	✱✱✱	✱✱✱	✱✱
	CREATIVE	✱✱	✱✱✱	✱✱✱
	PRESCRIPTIVE	✱✱	✱	✱✱✱
	MULTICRITERIAL	✱✱✱	✱✱✱	✱✱
	RADAR	✱✱✱	✱✱	✱
	SIMULATION	✱	✱✱✱	✱✱
	DIAGNOSTIC	✱✱	✱✱✱	✱✱
	ANALYTICAL	✱✱	✱✱✱	✱✱
	SURVEY	✱✱✱	✱✱	✱
	STRATEGIC	✱	✱✱	✱✱✱

✱	*the degree of linkage between methods of the classes with the possibility of study into one of three areas of uncertainty research*	✱ *low or zero* ✱✱ *medium* ✱✱✱ *high*

actions, events, activities, in different dimensions. The overall analysis of the future can better influence the minimization of the effect of uncertainty than in the case of methods that recognize the reality in a piecemeal.

The fourth class of multicriterial methods uses quantitative and qualitative data for complex research problems. These methods help in the classification and selection of alternative actions, with a large

number of decision-making criteria. They are used to determine the optimal priority issues. Therefore, methods of this group have a strong potential to identify and analyse areas of uncertainty.

Most methods of the radar class refer to an analysis of the current and past so that these methods can be checked in the identification of the various aspects of uncertainty. They focus on monitoring, categorization, typology, classification, identification of networks, analysis of the influence analysis of various sources in order to detect important signals regarding the latest research discoveries, technological innovation and any potential opportunities and threats.

The simulation class focuses on hard (quantitative) methods of mathematical perspective. The most characteristic features of this cluster are analyticity, back to work in a virtual environment, the nature of graphic, using secondary data, generate codified results. Thanks to the methods of this group, it is possible to measure the numerical level of uncertainty in extreme cases, receiving the form of the risk.

The purpose of the methods belonging to the diagnostic class is a systemic recognition, analysis and assessment of the current state of the object as well as the quality-strategic identification, assessment, and management of potential problems, constraints and associated uncertainty, among other solutions from other systems using objects.

Analytical methods allow defining a long-term assessment of developments in selected areas, indicating their intensity and level. These methods allow identifying the breakthrough phenomenon (e.g. technology) products, potential strategies, legal regulations related to the examined areas, as well as solutions to specific problems. In the context of uncertainty research, the analytical methods are characterized by similar characteristics of the diagnostic class.

Methods of the survey group, in the context of uncertainty research, have a similar interpretation to the radar methods. They assist in the evaluation of available secondary data, such as publications, reports, newsletters, databases, directories, statistics, etc. The survey class is characterised by reflective, logical approach, based on the analysis of the current state of knowledge regarding the study area (both in the strictly scientific way, as well as based on simple observations).

The methods of the strategic class are helpful in planning, scenario building, solving the complex problems of decision-making and change management, strongly taking into account the conditions of uncertainty. They assist in the formulation of the final results of the final projects while discovering the key factors and developing trends in the context of science, innovation, and technology.

Referring to the above analysis, it is clear that classes of foresight methods have the strongest relationship with the areas of identification and analysis of uncertainty. The strongest relationship for minimizing the phenomenon of uncertainty refers to the creative, prescriptive, and strategic classes.

Conclusions

The logic of human behaviour involves actual indefiniteness, real change, and the lack of continuity. The formation of a future situation affects a vast number of variables, among which occur those partially or completely undefined (Samecki, 1967).

In a number of future events, there is a lack of statistical repeatability as well as it is difficult to speak about the possibility of using deterministic models.

Foresight is one of the significant scientific considerations for the future that take into account the conditions of uncertainty and treat research object (country, region, company, society, etc.) in a systematic way. Despite several decades of foresight presence in the field of science, it still requires unambiguous formulation, especially in terms of methodical knowledge, relating to the management of uncertainty.

It is believed that dealing with uncertainty is the main task of entities that take strategic decisions. This is due to the treatment of various organisations (countries, regions, enterprises) as social beings, in which uncertainty will decline provided steps are taken to rationalize the activities of these organisations (Łuczak, 2012). Such activities include undoubtedly the future operation of foresight.

Predicting the future regardless of the time horizon, it is always associated with some degree of uncertainty. The greater and more complex areas of reality are examined (Samuelson & Marks, 1998).

At present, we have a number of definition of uncertainty. Analysis of this phenomenon in the context of the future of complex reality can use theoretical assumptions of the indeterminacy principle by Heisenberg. We can say that the uncertainty lies in the fact that the observer of the tested system at a given time and place, is not be able to determine the further functioning of this system with complete certainty (Zawiła-Niedźwiecki, 2007).

According to the author, the goal established in the article has been achieved. Relationships of sys-

temic research of foresight to research of the uncertainty phenomenon were identified and analysed. The author characterized the classes of foresight methods, by which it is possible to switch off their relationship to the process of testing the uncertainty using three aspects: identification, analysis, and minimizing. In addition, the rationality of the system's anticipation of the future was demonstrated in order to make appropriate practical decisions assuming occurrence of uncertainty regarding the behaviour of systems at the same time accepting the non-deterministic perception and the understanding of reality.

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Techniques for designing value propositions applicable to the concept of outcome-economy

Sylwia Gierej

ABSTRACT
The purpose of this article is to analyse and present some techniques that support the design of a value proposition in the context of the outcome-economy. The proposed techniques are intended to support traditional companies in the design of innovative solutions. Also, the discussed techniques were compared to identify the most effective. The study was conducted based on the information available in the literature on the impact of the Industrial Internet of Things on the economy and creation of a value proposition.

KEY WORDS
Industrial Internet of Things, Minimum Viable Product, outcome-economy, persona, Value Proposition Canvas, Value Proposition Design

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Introduction

The digital revolution changed the perception of the economy and business. Nowadays, the goal of most IT providers is delivering systems that are as intelligent as possible. The increased use of mobile technologies and cloud computing initiates changes in the design of applications and the ways of their use. The possibility of communication between machines and the analysis of the acquired data without human intervention allows to monitor and automate many processes. It drives to the growing importance of the Internet of Things. Therefore, companies are somehow forced to redesign their products and reorganise activities aiming for specific benefits for the client to survive in the market. A value proposition plays an important role in the development of innovative

products and services. It should be mainly focused on understanding the client preferences, which should be based on the use of techniques to facilitate data collection and analysis of potential recipients.

1. Outcome-economy as a stage in the development of the Industrial Internet of Things

The concept of the outcome-economy was created following the observation and analysis of the impact the Industrial Internet of Things (IIoT) had on business development. IIoT is understood as the use of technology in combining the data on people, machines, and processes through the network, contributing to a new direction of economic development (Vermesan & Friess, 2013). The concept of the Internet of Things was first used by a British entrepreneur, Kevin Ashton in 1999. He used it to name the communication system of the material world with computers by using sensors. This concept involves a combination of clearly identifiable devices via a computer network. Objects thus have the possibility of direct or indirect data collection, processing or exchange (Ashton, 2009). Beyond smartphones and tablets, devises connected within the IoT are also household appliances, lighting, and heating as well as wearable devices, even plants (Harris, 2014). At the turn of 2008 and 2009, the number of devices connected to the Internet exceeded 7 billion. It shows the growing importance of the Internet of Things (Magruk, 2015). Now is considered an appropriate moment to initiate the development of the Internet of Things. CISCO Systems Inc. has formulated a broader concept of this phenomenon, namely, the Internet of Everything. This concept defines the connection of people, processes, and data via the Internet (http://www.ioeassessment.cisco.com/). Analysis of the development of IIoT in economic terms distinguishes four phases of development (Fig. 1).

Phases 1 and 2 include measures feasible in the near future. The first step is to improve operational efficiency. Presented activities are currently being implemented, and will probably accelerate in the next two years. Phases 3 and 4 include forecasted trends, resulting from the growing influence of the IIoT. They are referred to as the outcome economy and pull economy. The outcome economy is based on the quantitative capabilities arising from the application of the IIoT. The economy based on sales products and services will change the direction of the development towards selling measurable outcomes (*Industrial Internet*…, 2015). *"Companies create value not just by selling products and services, but by delivering complete solutions that produce meaningful quantifiable business outcomes for customers"* (Barkai, 2016, p. 3). The term outcome should be understood as indicators that reflect the capacity of the enterprise to meet specific market needs, not the product specifications,

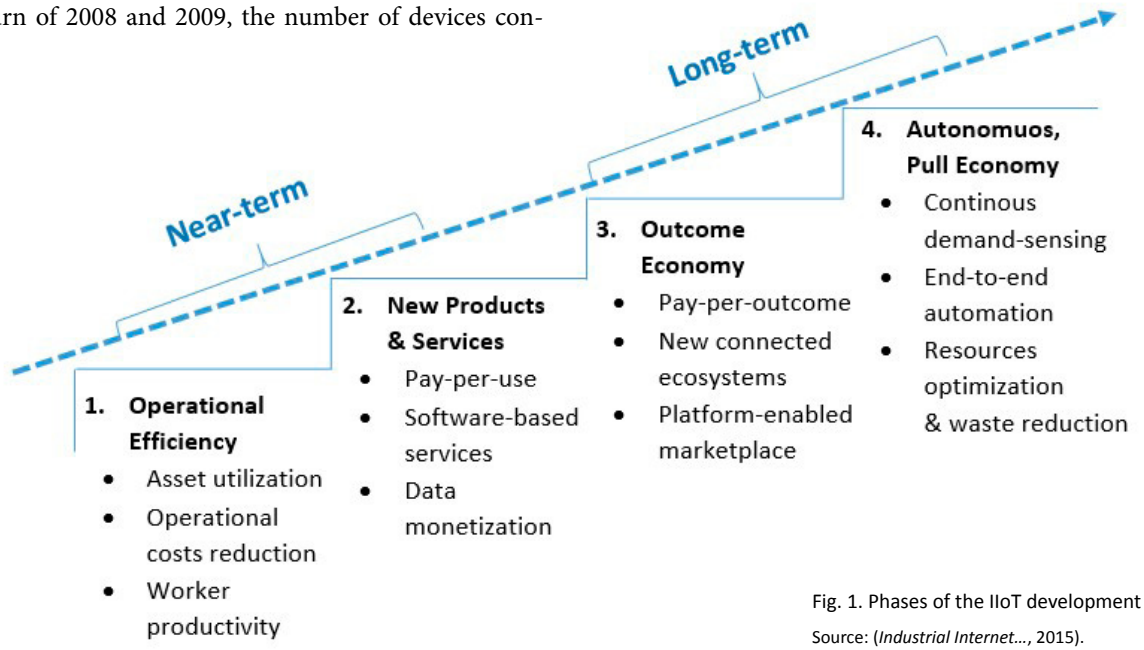

Fig. 1. Phases of the IIoT development
Source: (*Industrial Internet…*, 2015).

for example, horsepower. This is a big change that can bring modification of the basic structures of the industry and market competition. So far, the company based its operation on delivering high-quality products or services, competitive prices, creating a brand by building relationships with customers. The current technologic development forces producers to lean towards a more precise knowledge of preferences and attempts to predict customer needs. Running a business based on cooperation will be an important issue in the economic development. Experts from Accenture, telling about the outcome economy, use the following wording: "Hardware producing hard results". Enterprises operating in the traditional market will have to cooperate with partners who will provide them with the appropriate hardware and software. This will help move products from the physical business world to the digital market (*Accenture Technology*…, 2015). The main purpose is no longer the new products and services design. Companies will seek to improve the current offer by digital technology. In the long term, companies will be able to generate value without having the necessary resources. They will be able to rely on the assets, that in whole or in part, belong to others (Barkai, 2016). Some examples of the market functioning according to this model are already available, for example, Uber (http://www.uber.com) or Airbnb (http://www.airbnb.com). This solution provides the customer with the best value proposition resulting from the purchase of offered goods. The above-mentioned actions lead to phase 4, which is the spread of the IIoT in every industry. As a result, it leads to the possibility of determining the level of demand in real-time and highly automated and flexible production networks. The described phenomenon is referred to as the pull economy (*Industrial Internet*…, 2015).

2. Importance of the value proposition in the context of the outcome-economy

In practice, the concept of a value proposition is often thought to be the same as an offer of the company. However, the value proposition is not about presenting specific products or services offered by the company. The value proposition is the reason why customers choose the offer made by a company rather than its competition. In other words, the value proposition is the aggregate of benefits provided by customers using products or services (Osterwalder & Pigneur, 2010).

The value proposition consists of a defined set of components that meet the specific needs of a particular group of customers. These elements can be either quantitative or qualitative. The elements of a quantitative nature include, inter alia, price, speed, efficiency, lower costs. A group of elements of a qualitative nature may be: innovation, efficiency, design, brand, availability, convenience, and utility (Osterwalder & Pigneur, 2010). Great value propositions should have the following set of features (Osterwalder et al., 2014, pp. 72-73):

- Embedded in a great business model;
- Focused on jobs, pains, and gains that matter to most customers;
- Focused on unsatisfied jobs, unresolved pains, and unrealized gains;
- Targeting few jobs, pains, and gains, but doing so extremely well;
- Going beyond functional jobs and addressing emotional and social jobs;
- Aligned with how customers measure success;
- Focusing on jobs, pains, and gains that a lot of people have or that some will pay a lot of money for;
- Differentiating from the competition in terms of jobs, pains, and gains that customers care about;
- Outperforming competition substantially on at least in one dimension;
- Difficult to copy.

Based on the presented definition of the outcome-economy, which is oriented to the result of the actions, a value proposition can be considered as one of the key elements of corporate strategy. It should also be noted that the outcome-economy is one of the stages of development of the IIoT. Innovative solutions that are the result of technologic development are exposed to a high risk of failure in the market. This is the argument for companies that choose to introduce this type of goods, and which should attach great importance to examining the interests and needs in relation to the proposed solution.

New technologies contribute to the development of new habits and behaviours. These, in turn, are the new sources of economic value. This gives rise to the need for more innovative solutions. The ability to deal with this cycle is not dependent on the capabilities of machines and networks but on the substantial changes in the process value generation (Barkai, 2016). This is a big challenge for current managers, who develop a working method based on the quanti-

tative analysis. This option is helpful in the case of known solutions, which have already been verified by the market. The problem arises when the company deals with creating innovative products and services. Then, it is not possible to analyse the data, because a company simply has none before testing the solution, at least in the form of a prototype. Managers should have the ability to distinguish optimization measures for the current state of implementation of innovations. This does not mean that they should not in any way verify and collect data before the introduction of the new offer to the market. A compromise is to use advanced analytical tools that do not work well for innovative actions in favour of design methods. Managers should verify the innovative ideas on a small scale, so as not to incur high costs at the very beginning of the project. Data should be generated by conducting experiments. Continuous experimentation helps to make a suggested solution more convincing as well as produces new data. By doing so, modern managers can keep their analytical standards to a certain extent without sacrificing them to innovation because of insufficient information (Martin, 2014).

3. Selected techniques used in the process of design of a value proposition

3.1. Description of the process of design of value propositions based on selected concepts

The vast majority of the methods used to define the value proposition comes from start-ups – innovative ventures looking for a scalable business model. They are the most versatile and successful and can be used in enterprises, which have so far operated in the traditional market and decided to introduce their offer on the digital market. Before discussing some design methods, we should look at the process of design of a value proposition. The author decided to compare three approaches to building value propositions, and then indicate the necessary steps in this process.

The first is the concept of Customer Development, which assumes a division of all activities associated with customers into separate processes and incorporates them into four stages. The first two stages relate to the search for the right business model, while two others – to the implementation of the defined and verified positive business model. However, bearing in mind that the key role in the described approach fully corresponds to the client needs, it is possible to look at it in terms of creating value propositions. Steps of the customer development methodology are presents the following diagram (Fig. 2). Stop signs and arrows in the diagram indicate the need for experimentation, verification and implementation of any changes (Blank & Dorf, 2012).

The second analysed concept is running the Lean methodology. It is defined as "the systematic process of iterative transition from plan A to plan B effectively, even before running out of resources". The development of the initial action plan should be the first step in creating innovative solutions. It should focus on defining the problem and groups of customers of the company. The next step is to consider the elements that may pose the biggest threat. In most cases, the biggest threat is to work on a solution that ultimately is not intended for their audience. For this reason, first, the focus should be on elements that are associated with the highest risk (Maurya, 2012). The development of innovative solutions can be divided into three stages: Problem/Solution Fit, Product/Market Fit, and Scale (Fig. 3).

The third approach discussed is the idea, which is derived from the concept of Business Model Canvas (BMC). In the business model per Osterwalder, value proposition it is one of the fundamental elements necessary for a profit of a company. Continuing the work, the author of this concept developed a scheme of conduct in the value proposition design. Under

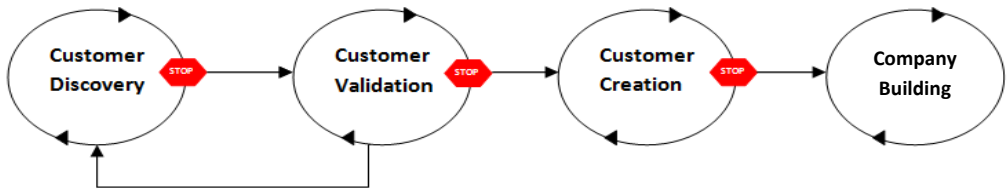

Fig. 2. Steps of the customer development methodology

Source: (Blank & Dorf, 2012).

Fig. 3. Three stages of the start-up development

Source: (Maurya, 2012).

this scheme, four steps are distinguished (Osterwalder et al., 2014):

1. Canvas – at this stage, the author proposes the use of two patterns: Customer Profile and Value Map, which will indicate the main characteristics, needs and concerns of potential customers, and then compare them with the benefits offered by the company.
2. Design – prototyping solutions to verify the developed assumptions.
3. Test – conducting experiments and analysis of the collected data to minimize a risk.
4. Evolve – the introduction of the product while continuing monitoring and analysing performance, and possible modification of assumptions.

After comparing the presented concepts, it turns out that all of them are based on a very similar flow chart. The first step is a preliminary analysis of the profile of a potential customer, its problems and needs, and then a summary of the features of the proposed solution. In other words, the company initially verifies that the offered product or service has any value to the customer. The next step should be to test assumptions rather than go forward with the project implementation, as it happens in most cases. The obtained feedback makes it possible to change the product in the way that increases the value proposition. This will allow the company to minimize the risk of losses incurred in the form of expenditures that occur in the absence of a product on the market. The final step is the introduction of the final product on the market. This does not mean the end of the analysis of feedback from customers as it should be continuously monitored and analysed.

3.2. Characteristics of selected techniques for the design of a value proposition

The literature provides several techniques for the design of a value proposition. Their main purpose is to facilitate the collection and analysis of data on potential customers and tested solutions. The author decided to describe the techniques and tools that are currently gaining popularity. Most of them are based on visual creation, analysis, and exchange of information.

The first technique is the approach proposed by Osterwalder, already mentioned in the previous section. It is the template of the Customer Profile and the Value Map. It is based on the concept of the Business Model Canvas (Fig. 4). It involves creating a business model with the use of a template consisting of nine fundamental elements. A value proposition is placed in the central part of the model (Osterwalder & Pigneur, 2010).

The primary tool for supporting the development of the contents of fields that describe the customer segments and the value proposition is the Empathy Map (Fig. 5). The use of the Empathy Map aims to develop a profile of a potential customer. It helps to go beyond the typical demographic characteristics of the target audience and better understand the environment, behaviour, concerns and aspirations of its people. The acquired knowledge helps to build more efficient business models, and the creation of the customer profile leads to the development of a better value proposition, efficient methods of contact with customers, and more appropriate relationship with them. In other words, the customer profile of the customer to better understand what it is willing to pay (Osterwalder & Pigneur, 2010).

The Value Proposition Canvas (VPC, Fig. 6) is to discuss and design connections between the Empathy Map and fields of the BMC. VPC focuses exclusively on two fields maps, namely value proposition and

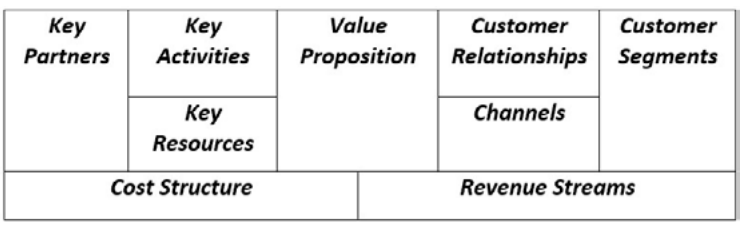

Fig. 4. Business Model Canvas

Source: (http://www.businessmodelgeneration.com/, 2016).

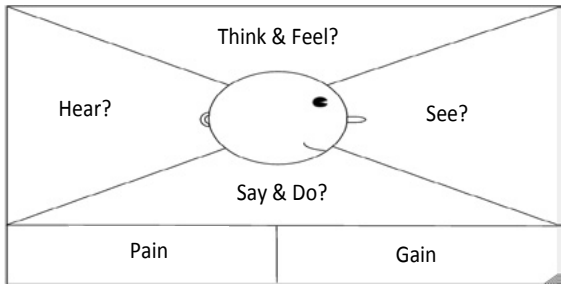

Fig. 5. Empathy Map
Source: (Osterwalder & Pigneur, 2010).

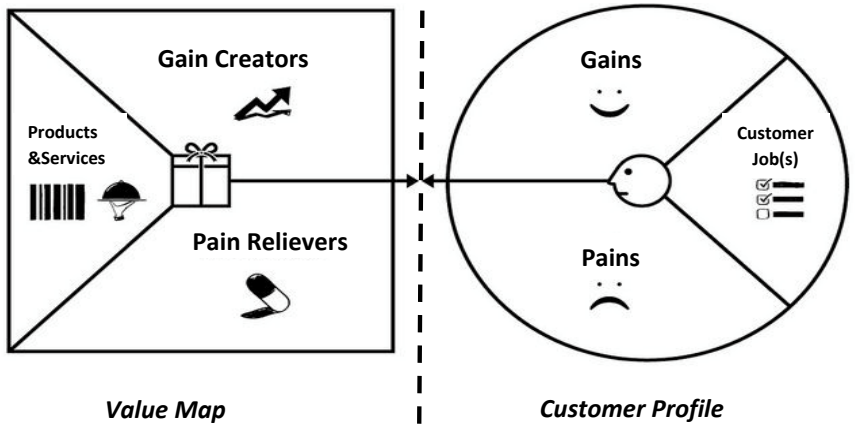

Fig. 6. Value Proposition Canvas
Source: (Osterwalder et al., 2014).

customer segments. Its task is to design connections (distribution channels and customer relationships), to create the products best suited to the needs of its customers. On the one hand, VPC provides the analysis of the market and customer expectations, on the other hand, it determines the tasks that must be performed to match the expectations. It may happen that customer expectations are also concerned with the way a service or product is built, and will force the company to reorganise the infrastructure (Osterwalder et al., 2014).

Below characterized individual elements VPC:

- Customer Job (s): The beginning of the analysis should be a thorough understanding of the target group. It should try to find out and analyse the tasks performed by customers every day. Attention should be focused on matters concerning the problem area related to the proposed solution.
- Pains: This element is designed to identify any obstacles that arise during the planning and implementation following the above-mentioned tasks. It will be all kinds of negative emotions, risks, contingencies, and costs. Consider the solutions currently used by customers and what they consider to be too expensive, difficult or annoying.
- Gains: The next step will be to determine the benefits of these tasks. The benefits can be any kind of positive emotions, social benefits, satisfaction, savings, and increased profits. The focus should be on finding out what pleases the customer, the solutions he/she likes, and things that make his/her life better.
- Products & Services: Having developed the profile of the client, the company can offer a solution that is a value proposition. In the beginning, it should note products and services that a value proposition contains.
- Pain relievers: Creating value for the customer to either relieving the pain or strengthen the applicable benefits. It should be considered how the proposed solution affects the pain of the potential customer.
- Gain Creators: It should also look at the benefits offered to the customer by the proposed product. It should refer to a predetermined positive aspect, which is desired by the customer.

The analysis of the customer needs, benefits and pains clarifies at least some of the proposals that the company can offer. It should examine each of the proposals using the VPC. The right side of the canvas should remain unchanged, and the left side should produce several solutions and compare them with each other. It can also describe the solution proposed by the competition and make the comparison with the own product. The Value Proposition Canvas is a starting point to begin work on the conceptual idea. There is no need to focus immediately on a full business model, but to explore customer needs and examine possible solutions. The advantage of the canvas is also to draw attention to two important areas of value creation for the customer: benefits and pains. That is what they should look for in a unique value proposition for your product or service (Osterwalder et al., 2014).

Create a persona is another technique, aimed at creating an image of a potential customer and aiding the design of a value proposition. Persona is a model

of a typical user of a product. The characteristics of a persona are developed based on the analysis of data obtained from tests performed on users. Appropriate use of the findings supports strategic actions related to the objectives and functionality of the designed solution. A persona should be developed in the initial phase of creating a prototype because the product should be developed and optimized for users. Information about users is acquired based on research, such as in-depth individual interviews, focus group interviews, surveys, statistics of website visits and observations. They allow getting information on the objectives and motives of behaviour and the impact of the environment on the user. Studies necessary to create a persona are costly and time-consuming. However, to the result is a developed model of a potential user. Archived data can be used. In the case of construction of a company website, there is a breath of customer information on marketing or sales. By creating a persona, a prototype is created based on the habits and activities of the target group, and not the characteristics of a designer. This allows keeping only the necessary functions, all of which will be used by the potential user (Kasperski & Boguska-Torbicz, 2008).

The analysis of the customer profile and the desired characteristics of the solutions is followed by the stage of creating the project product or service. It should prepare a prototype that will be used to test the solution on a small scale. One of the techniques is used in the preparation of a prototyping under the Viable Minimum Product (MVP). This is a version of the solution that is minimally ready for the market. It is sufficiently specific to show the prospective customer value and allow the company to measure the interest of the customer. The main objective of the creation of the MVP is to collect as much information as possible with the least effort. This approach allows testing the validity of the idea. This gives a huge advantage over the classical approach to making products for sale. The classic approach assumes that the process starts with the product hitting the market, i.e. with market research, approval, logistics, manufacturing, marketing, sales, and customer service. It is a very expensive operation, which may prove unsuccessful. The MVP helps to save time and costs and to carry out consumer research on a specific product, service, and application (Maurya, 2012).

Based on the information available in the literature, the assessment was made considering the following criteria: the cost of the use of technique, ease of use, required expertise and equipment, and understanding of the technique by all members of the organisation. The rating of techniques was presented in Table 1.

The cheapest, yet easiest to use techniques are the Empathy Map and the Value Proposition Canvas. They do not require specialized facilities or expertise or skills. They can be used successfully at the beginning of work, as well as supplemented with additional information in the later stages of a project. They can provide the basis for two other techniques: persona and MVP. Their use is associated with higher costs because they require more detailed information about potential users. In addition, in the case of the MVP, the organisation creates the basic test version of the product, which also requires additional funding, staff with appropriate skills and proper technological facilities.

Tab. 1. Rating of the techniques for the selected criteria

Criterion	Empathy Map	Value Proposition Canvas	Minimum Viable Product	Persona
Costs	***	**	*	*
Ease of use	***	***	**	**
Required specialised expertise	***	***	**	**
Required specialized infrastructure	***	***	***	***
Understanding by all members of the organisation	***	***	*	***

The assessment scale of techniques for each criterion ***(very good), **(average), *(poor)

Source: author's elaboration based on (Osterwalder & Pigneur, 2010; Osterwalder et al., 2014; Maurya, 2012; Kasperski & Boguska-Torbicz, 2008).

Conclusions

Development of technologies contributes to changes in every aspect of life. The digital revolution has a significant impact on business. The use of technologies in combining the data on people, machines, and processes through the network improves business operations. Attempts are made to enrich the physical goods with features based on digital technology, which can raise the value proposition of a company. Development of the IIoT drives the economy

toward the creation of companies whose business models are focused on providing customer-specific values and benefits. The presented techniques are used in the process of designing value propositions. They are mainly used in the initial stage of the process, the aim of which is to accurately define preferences of potential customers. Creating a customer-tailored solution increases the chance of greater interest in the product while minimizing the risk of an unfortunate investment. The use of such techniques is essential for creating innovative products, as in the case of such solutions often lack data, based on which managers can make decisions. The process of creating a value proposition should start with the use of techniques, which are simple and cheap to use. Such techniques include, among others, Empathy Maps and the Value Proposition Canvas. Thanks to them, an organisation is able to develop the initial product vision. To verify the initial assumptions, another technique can be used, namely, the Minimum Viable Product. It allows you to test the basic functions of the product and obtain feedback from customers to design the final solution.

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Modelling contractor's bidding decision

Sławomir Biruk, Piotr Jaśkowski, Agata Czarnigowska

ABSTRACT

The authors aim to provide a set of tools to facilitate the main stages of the competitive bidding process for construction contractors. These involve 1) deciding whether to bid, 2) calculating the total price, and 3) breaking down the total price into the items of the bill of quantities or the schedule of payments to optimise contractor cash flows. To define factors that affect the decision to bid, the authors rely upon literature on the subject and put forward that multi-criteria methods are applied to calculate a single measure of contract attractiveness (utility value). An attractive contract implies that the contractor is likely to offer a lower price to increase chances of winning the competition. The total bid price is thus to be interpolated between the lowest acceptable and the highest justifiable price based on the contract attractiveness. With the total bid price established, the next step is to split it between the items of the schedule of payments. A linear programming model is proposed for this purpose. The application of the models is illustrated with a numerical example.

The model produces an economically justified bid price together with its breakdown, maintaining the logical proportion between unit prices of particular items of the schedule of payment. Contrary to most methods presented in the literature, the method does not focus on the trade-off between probability of winning and the price but is solely devoted to defining the most reasonable price under project-specific circumstances.

The approach proposed in the paper promotes a systematic approach to real-life bidding problems. It integrates practices observed in operation of construction enterprises and uses directly available input. It may facilitate establishing the contractor's in-house procedures and managerial decision support systems for the pricing process.

KEY WORDS

decision support; decision to bid; pricing strategy, contractor cash flows, linear programming

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Introduction

Tendering stays one of the most popular means of selecting contractors to carry out construction works. Any invitation to tender is an opportunity, and thus the contractor needs to decide if to explore it (use time and resources to prepare a bid) or decline it in search for better options. Several factors need to be considered in the process of decision-making. The contractor's experience and business intuition are not enough to ensure that the tender procedures entered by the contractor offer a good trade-off between costs (bid preparation costs including the opportunity cost of using the scarce time to prepare this bid and not the other) and benefits (winning a contract that is profitable, would maintain the contractor cash flows, or allow them to win a better market position).

With an invitation to tender accepted, a decision on the bid price needs to be taken. Apart from items defined in the tender documents, whose cost can be simply calculated, many components of the price are estimated based on a less tangible input; these are risks and profit. The bid price is expected to be high enough to guarantee that the contractor recovers all costs and earns a decent profit and, at the same time, low enough to beat the competition. Low bidding increases chances of winning the contract but reduces chances of making a profit. Therefore, the contractor's decisions whether to bid and later what price to offer, are complex and call for decision support tools. The paper puts forward models that facilitate rational decision-making in terms of bid/no-bid, unit rate pricing, and defining the overall price of a job. The focus of the models is on maximising the net present value of the project cash flows (excess of sums to be received from the client over cost). Application of the models is illustrated with a numerical example.

1. Literature review

1.1. Decision to bid

A contractor's bidding department can produce only a limited number of bids at the same time. A decision to assign resources to the analysis of one client's invitation to bid implies that other invitations are rejected. A quick selection of most promising invitations poses a practical problem, and, therefore, literature is rich in analyses of selection criteria and methods.

The first question, which is relatively simple to answer, is what criteria affect the contractor's decision to tender. Estimating and tendering handbooks provide guidelines on selection criteria based on the experience of their authors (among others, Brook, 2011, p. 96; Cartlidge, 2013, p. 3; Stevens, 2012, p. 93). Enquiries on factors affecting the bid/no bid decision were conducted in many countries: in Great Britain (Shash, 1993), Egypt (Hassanein, 1996), the United States (Ahmad & Minkarah, 1998), Syria (Wanous et al., 2000), Singapore (Chua & Li, 2000), Saudi Arabia (Bageis & Fortune, 2009), Poland (Leśniak & Plebankiewicz, 2015), Australia (Shokri-Ghasabeh & Chileshe, 2016), and Nigeria (Oyeyipo et al., 2016). As the authors drew from each other, the lists of initial criteria were rather consistent regardless of the country of origin. Criteria rankings presented in the literature varied considerably, although the most significant factors in the decision to bid usually include the client's reliability, the need for work, the expected number of competitors (chances to win the job), and experience with such projects. This may be attributable, on the one hand, to economic conditions varying strongly according to the location and the date of the survey. On the other hand, the profile and number of interviewees, as well as ranking methods, strongly affected the results. In the above-presented studies, the most popular methods of pointing to key criteria were based on average scores calculated according to individually adopted crisp or fuzzy scales, with a more or less rigorous approach to checking the consistency of opinions and the reliability of findings.

With the criteria at hand, numerous methods were proposed to compare invitations to bid to find those potentially most promising. Some authors aimed at creating models based on records on qualities of previously selected invitations to tender allowing the user to assess a particular invitation as worth or not worth considering. These models were either parametric, such as logistic regression (Lowe & Parvar, 2004; Hwang & Kim, 2016), or non-parametric, for instance, based on artificial neural networks (Wanous et al., 2003). Complex knowledge-based expert systems can also be found in the literature (Egemen & Mohamed, 2008).

Other authors applied multi-criteria analyses to provide a ranking within a set of options. The methods range from the simplest additive scoring models (Stevens, 2012), to allowing for the imprecise and subjective character of input by using fuzzy logic (Lin & Chen, 2004; Tan et al., 2010). With the wide selection of multi-criteria methods constantly developed (Saaty, 2000; Triantaphyllou, 2000; Köksalan et al., 2011), these examples present but a small fraction of research on the subject.

1.2. Defining the bid price when cheapest bid wins

According to Mochtar and Arditi (2000), construction pricing strategies can be divided into two groups: cost-based pricing and market-based pricing. Most models presented in the literature assume that the definition of the price is a two-stage process that comprises "first the calculation by the estimator of the true commercial cost to the contractor/subcontractor, followed by the adjudication or settlement process…" (Cartlidge, 2013, p. 221). The latter consist of adding allowances for cost-affecting risks and

uncertainties, company overheads and profit to obtain the bid figure (Mochtar & Arditi, 2000). This traditional approach to costing is suitable in traditional procurement routes, where the contractor has little influence on materials and construction methods, i.e. the factors that determine most construction costs.

Another group of models uses the concept of market-based pricing (Best, 1997) or target costing (Cooper & Slagmulder, 1997), where the price is prompted by the demand side of the market and objectively corresponds to the client's perceived value of the job. If this can be established, the contractor (or, in fact, the whole value chain that cooperates to satisfy the client) strives to "engineer" the cost of providing the service, at the same time, sell for this market price, and reach the profit targets. From the viewpoint of a construction contractor, it is impossible to apply target costing to traditionally procured projects as the product (a built facility) is made to detailed specifications prepared in advance by other entities. However, schemes with a higher level of integration of design, construction and ongoing maintenance of the built facility are a perfect object of target costing (Sobotka & Czarnigowska, 2007; Potts, 2008; Kaka et al., 2008).

Models within the first group facilitate the decision on the mark-up level by maximising the expected value of contractor's profit while bearing in mind the probability of winning the contract, which drops with the increase in the price and the intensity of the competition (number of bidders). Early models of this kind, based on the probability theory and statistical patterns observed in bidding by the competitors were proposed by Friedman (1956) and Gates (1967), and were later verified, modified, expanded or criticised by many researchers (among others, Benjamin et al., 1979; Carr, 1982; Ioannou, 1988; Mielec et al., 2009). These models assume that a detailed knowledge of competitors (their number in the bidding procedure, historical records of their prices) is available and that behaviour of competitors is going to be repeatable, as keeping to the pattern of the bid price and the cost probability distribution assessed based on historical data.

In the case of bids related to complex projects of unique scope, the price is the result of elaborate calculations of direct and indirect costs that allow for fluctuations in resource prices. Other factors that affect the contract's attractiveness from the contractor's point of view need to be accounted for. They may provide justification for reducing mark-up to improve chances for getting an attractive job (big, prestigious, or just badly needed in the times of recession). They may also provide justification for inflated mark-up that reduces the probability of winning the contract to compensate for additional related risks, e.g. with undefined scope in fixed price contracts, or just to use the opportunity. Thus, current objectives may not be convergent with the long-term aims of maximising the expected value of profit, and statistical methods may be not enough to depict such complex relationships. Therefore, many authors refer to artificial intelligence techniques that capture relationships between contract properties and mark-up value, consider more criteria than just profit maximisation, and allow for the uncertainty of input using, e.g., fuzzy logic. Tools based on Artificial Neural Network have been proposed by, among others, Moselhi et al. (1993), Li and Love (1999), or Leśniak and Plebankiewicz (2013). Wang et al. (2007) integrated cost model and multicriteria evaluation to provide a more flexible way of defining the bid price.

In general, the authors of most pricing models meant for typical construction tendering problems (sealed auction, lowest bid wins) agree that:

- the decision whether to bid is an individual and multi-criteria problem;
- the bid price should be economically justified, and this means different things in different circumstances (another multicriteria problem).

2. Research methods

The authors propose to calculate the aggregated score O of the overall desirability of the contract (approach put forward by, among others, Lin & Chen, 2004) according to the arbitrarily assumed set of criteria. The set of criteria is likely to be individually decided by the contractor, according to the type of project and economic circumstances, and, therefore, the authors refrain from proposing a fixed list of criteria. The aggregate score O, a single value, is to be compared with an arbitrary threshold – the lowest score that supports the decision to bid.

To calculate the total desirability score, the authors decided to use simple additive weighting method:

$$O = \sum_{i=1}^{n} o_i \cdot w_i, \quad \sum_{i=1}^{n} w_i = 1, \quad o_i \subset \langle 0,1 \rangle, \qquad (1)$$

where:

o_i – represents the normalised score, and

w_i – the weight of a particular criterion i of n criteria used for analysis.

Considering the findings on bid/no bid decision criteria presented in the literature, the criteria can be divided into three to four groups, each with a set of specific sub-criteria. The assumption is, the sub-criteria scores are to be given by an expert, and scores are to be expressed in the intuitive linear scale between 0 (worse) and 1 (best). The value of 0.5 means that, according to this criterion, there is a minimum justification for accepting the invitation. Thus, the aggregated score $O = 0.5$ is the lowest score that supports the decision to bid.

Values of criteria weights w_i are to be established by means of the Analytic Hierarchy Process (Saaty, 2000), again using the expert opinion of the managers. The Analytic Hierarchy Process (AHP) is a popular decision-making method where variants are evaluated using both quantitative and qualitative criteria, suitable for determining relative weights of compared alternatives. It is easier for a decision maker to define relative dominance than to provide the direct value of weight.

In AHP, the main goal, criteria, and sub-criteria create a multi-level hierarchical structure (which corresponds well with the idea of using bid/no bid sub-criteria that form generic groups). The decision -making process was replaced by a consecutive sub-problem solving, defined at the same level. Calculations on each level of the hierarchy are repeated according to the same rules of the pair-wise comparison with respect to the element in the immediate upper level. Decomposition of the problem implies that a relatively small number of comparisons is to be made on each level. The method also provides measures of judgment consistency, so results can be verified (Saaty, 2000; Kou et al., 2013).

For the next step of the analysis, determining the bid price, the authors assume that the bid price, C, is a function of the project attractiveness, O (Fig. 1). The score of the overall attractiveness of the invitation to tender is to be used for interpolation of the contract price between two predefined values: the maximum total bid price C_{max} and the minimum total bid price, C_{min}.

C_{max}, understood as the highest justifiable price, is to be calculated on the basis of maximum resource prices and highest mark-ups (overhead and profit) reported in the market. Input for the calculation of

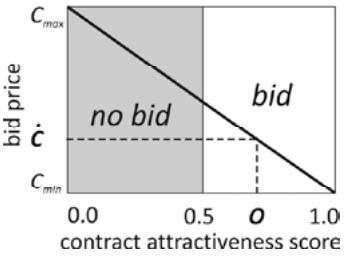

Fig. 1. Bid price interpolation

C_{max} may come from construction price books; historical rates should be adjusted for time according to expected trends in construction prices.

The minimum total bid price C_{min}, is considered the lowest sum to cover all project costs estimated according to the most probable scenario for the development of construction prices. Formulas (2)–(7) represent the linear programming model proposed for determining C_{min}, and distributing it among items of the schedule of payments by defining unit prices of items, c_j, in a way that makes the contractor's discounted surplus non-negative. This way, the authors decide to use the cost-based approach to pricing, assume that "suicide bidding" is not to be considered, and that it is possible to objectively calculate the cost.

To calculate C_{min}, one needs to prepare a schedule of payments and a schedule of works to define the amounts to be received and to be paid in each unit of time, l, out of t units of time in the time for completion.

Formula (2) is the objective function minimising the total price being the sum of products of unit prices of the bill of quantity items, c_j, and their predefined quantities, q_j:

$$\min C: \; C = \sum_{j=1}^{m} c_j q_j . \tag{2}$$

Condition (3) is to assure that the service is not offered below the cost, so the net present value of the contractor's surplus of money received R_{jl} and money paid P_{lj} is non-negative:

$$NPV = \sum_{j=1}^{m} \sum_{l=1}^{t} d^l (R_{lj} - P_{lj}) \geq 0 , \tag{3}$$

In Formula (3), d is a discounting factor introduced to allow for the opportunity cost. The amount to be received in return for the item j at the unit of time l, is the product of the unit price of the item, c_j, and the quantity to be paid for by the client at the time unit l. This quantity is expressed as $q_j s_{jl}$, where q_j

is the total quantity of the work j, and s_{jl} is the fraction of the total quantity of the work to be paid, according to contract conditions, by the client at the unit of time l:

$$R_{lj} = q_j s_{lj} c_j . \quad (4)$$

The cost related to the item j payable by the contractor at the unit of time l, is a product of unit cost of the item, k_j, and the quantity of the item completed in this unit of time, $q_j p_{jl}$, where p_{jl} is the share of the total quantity of the item whose costs are to be paid by the contractor at the time unit l:

$$P_{lj} = q_j p_{lj} k_j . \quad (5)$$

The authors assume that all costs are contractor's payments at the unit of time they have been incurred, whereas the amount payable by the client may be based on different quantities, for instance, the client may pay only for items that are totally completed, with a certain delay from their physical completion, or retentions that are agreed in the contract. For this reason, s_{lj} and p_{lj} may be different.

Condition (6) ensures that unit prices for particular works are not too low or high in comparison to market prices: $c_j^{\min}$ and $c_j^{\max}$ are, respectively, minimum and maximum unit prices of the item j calculated on the basis of construction price books or individual market surveys, adjusted for the most probable scenario of construction price changes:

$$c_j^{\min} \le c_j \le c_j^{\max}, \ \forall j \in Q . \quad (6)$$

Condition (7) is to guarantee that unit prices of items stay in some logical relationship: if the cost of item v is naturally greater than the cost of the item u, their prices should reflect this fact. For instance, the unit price of mechanical excavation in heavy cohesive soil is naturally greater than the unit price of excavation in the light granular soil. In Condition (7), A represents a set of pairs of items whose unit prices are related this way:

$$c_u \le c_v, \ \forall (u,v) \in A . \quad (7)$$

Apart from quoting the total bid price, the contractor is usually required to submit a schedule of payments with values assigned to particular items defined in the client's breakdown structure, with special care to include all components of the rate according to the client's specification. Another linear programming model, described by Formulas (8) to (13), very similar to the previous one, is put forward for calculating the optimum unit prices, $\dot{c}_j$ of items.

The basis for this stage of analysis is the total bid price, $\dot{C}$, calculated previously according to the idea presented in Figure 1. With $\dot{C}$ defined, one can calculate the unit price $\dot{c}_j$ of each particular item in a way that maximises the contractor's cash flows:

$$\max NPV: \ NPV = \sum_{j=1}^{m} \sum_{l=1}^{t} d^l (\dot{R}_{lj} - P_{lj}), \quad (8)$$

$$\dot{R}_{lj} = q_j s_{lj} \dot{c}_j . \quad (9)$$

$$P_{lj} = q_j p_{lj} k_j . \quad (10)$$

$$\dot{C} = \sum_{j=1}^{m} \dot{c}_j q_j , \quad (11)$$

$$c_j^{\min} \le \dot{c}_j \le c_j^{\max}, \ \forall j \in Q , \quad (12)$$

$$\dot{c}_u \le \dot{c}_v, \ \forall (u,v) \in A . \quad (13)$$

Both these models can be solved by means of popular solvers, e.g. GAMS, LINGO, AIMMS, Lp_Solve.

3. Illustration of the method's application

The method proposed above was applied to a notional case of a construction project to build a six-storey office building. Table 1 lists sub-criteria, divided into four generic groups (project conditions, risk, contract conditions, contractor's standing), that were used as a basis for the bid/no bid decision. The criteria list was compiled arbitrarily based on literature review. Criteria scores, on the scale between 0 and 1, were defined during an interview with one expert based on the analysis of tender documents. Criteria weights were calculated by means of the Analytic Hierarchy Process using the pair-wise comparisons provided by the same expert.

The schedule of works is presented in Table 2. Payment conditions assume that the contractor shall be paid on a monthly basis for each completed element. There are no retentions in the contract.

The total cost of the project, as calculated by the contractor, was EUR 1,125,525.42. The maximum total price C_{max}, calculated based on maximum unit prices from price books, was EUR 1,390,876.33. The minimum total price, C_{min}, was calculated by solving

Tab. 1. Multi-attribute assessment of job attractiveness – justification for entering the competition

Criterion	Weight, w_i	Score, o_i (0÷1)	Weighted score, $w_i \cdot o_i$
1. Project conditions	0.2124		0.1153
– conditions to enter the procedure	0.0525	0.7	0.0367
– expected number and type of competitors	0.0280	0.4	0.0112
– relationship with the design team and the client team	0.0090	0.4	0.0036
– location	0.0117	0.7	0.0082
– time for completion	0.0195	0.5	0.0097
– profit earned in similar projects	0.0918	0.5	0.0459
2. Risk	0.1633		0.0929
– job uncertainty	0.0358	0.4	0.0143
– owner reputation	0.0071	0.6	0.0043
– owner financial standing	0.0652	0.7	0.0456
– quality of the bid documents	0.0266	0.4	0.0106
– technical difficulty	0.0204	0.6	0.0122
– availability of qualified subcontractors	0.0083	0.7	0.0058
3. Contract conditions	0.0655		0.0295
– duration and cost of bid preparation	0.0027	0.6	0.0016
– contract type	0.0029	0.4	0.0012
– term of payment	0.0270	0.4	0.0108
– warranty terms	0.0159	0.5	0.0080
– penalty conditions	0.0054	0.4	0.0022
– claim solution	0.0116	0.5	0.0058
4. Contractor's standing	0.5588		0.3841
– experience in similar project	0.2308	0.8	0.1846
– percentage of work to be subcontracted	0.0247	0.6	0.0148
– need for work	0.1390	0.7	0.0973
– qualified technical and managerial staff	0.0887	0.5	0.0443
– availability of resources	0.0507	0.7	0.0355
– financial statement	0.0249	0.3	0.0075
Total	1.0000		0.6217

the model with the objective function defined by Formula (2) and constraints (3) to (7). The discounting rate to calculate the discounting factor d was set to 1% per month. As for constraint (7), it was assumed that the unit prices of floor slabs and walls in the substructure should be greater than the unit price of floor slabs and floors of the superstructure because of differences in their design. The result, which is the minimum bid C_{min}, is EUR 1,241,260.32 and is considered to ensure that all costs (including opportunity cost) are recovered by the contractor. In the next step, the total bid price Ċ was interpolated according to the idea presented in Figure 1 to the amount of EUR 1,297,855.81.

The unit prices of particular items of the bill of quantities, $\dot{c}_j$, were calculated by solving the model defined by Formulas (8) to (13).

Table 3 presents the bill of quantities with information on unit costs k_j (direct and indirect) of each item, and unit prices:

- minimum c_{jmin} (directly from price books adjusted for expected changes over time), maximum c_{jmax} (directly from price books adjusted for expected changes over time), as required for Condition (6) and (12);
- calculated unit prices for the bid, $\dot{c}_j$, found by solving the model (8)–(13), with results rounded to two numbers after the decimal point.

4. Discussion of the results

Considering the results of the illustrative example presented in Section 3, the model, as expected, assigns the highest possible unit prices to the items that are to be completed by the beginning of the project to maximise the contractor's net present value. Unit prices of the items scheduled by the end of the project are close to the minimum prices.

Tab. 2. Schedule of works

No. (*j*)	Element	Percentage of work completed [%]															
		Month															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	Earthworks	0.9		0.1													
2.	Footing	1															
3.	Substructure walls		1														
4.	Substructure insulation and waterproofing			1													
5.	Substructure slabs & stairs		0.55	0.45													
6.	Superstructure walls			0.16	0.14	0.18	0.14	0.13	0.08	0.17							
7.	Superstructure slabs & stairs			0.02	0.14	0.17	0.17	0.16	0.17	0.17							
8.	Partitions									0.95	0.05						
9.	Roof – RC structure									0.34	0.66						
10.	Roof – timber structure									0.25	0.75						
11.	Roof drainage										1						
12.	Roof cladding										1						
13.	Screeds													0.43	0.57		
14.	Plasters										0.04	0.28	0.32	0.28	0.08		
15.	Interior tiling													0.12	0.56	0.32	
16.	Metal fixtures									0.1	0.15	0.1	0.2	0.2	0.25		
17.	Painting														0.52	0.41	0.07
18.	Flooring															0.83	0.17
19.	Windows & external doors										0.25	0.75					
20.	Internal doors																1
21.	Façade plasters											0.53	0.47				
22.	Façade cladding												0.78	0.22			
23.	Heat source														1		
24.	Heating system									0.15	0.22	0.24	0.19		0.05	0.15	
25.	Disposal system									0.22	0.09	0.09	0.1		0.25	0.25	
26.	Water system									0.25	0.08	0.09	0.18		0.26	0.14	
27.	Ventilation									0.25	0.12	0.12	0.21		0.09	0.21	
28.	Electrical									0.4	0.11	0.11	0.13		0.17	0.08	
29.	Communication									0.3	0.17	0.06	0.27		0.15	0.05	
30.	Lifts														1		

The model corresponds well to the logic of price calculation. However, it is not universal as based on several assumptions that may seriously reduce the practical applicability:

- The best bid is the cheapest bid (the model is not directly applicable to the tendering procedure with multiple criteria). The lowest price tenders remain one of the most popular approaches, especially in the case of subcontractor selection, but with currently observed trends of the clients searching for best value, it is certainly not the only one;

Tab. 3. Bill of quantities with unit cost and unit prices

No. (*j*)	Element	Unit of measure	Q_j	K_j, EUR/unit	C_{jMIN}, EUR/unit	C_{jMAX}, EUR/unit	$\dot{C}_j$, EUR/unit
1.	Earthworks	m^3	2364.60	34.02	36.22	41.50	41.50
2.	Footing	m^3	154.50	244.37	263.29	296.88	296.88
3.	Substructure walls	m^3	171.20	250.13	274.62	314.93	314.93
4.	Substructure insulation and waterproofing	m^2	1945.52	5.43	5.84	6.77	6.77
5.	Substructure slabs & stairs	m^2	322.30	55.73	59.24	71.10	71.10
6.	Superstructure walls	m^3	1082.70	188.93	203.83	228.24	228.24
7.	Superstructure slabs & stairs	m^2	1755.80	52.35	56.83	64.69	64.69
8.	Partitions	m^2	2058.30	12.92	13.88	15.48	15.48
9.	Roof — RC structure	m^2	177.20	35.99	39.56	43.71	43.71
10.	Roof — timber structure	m^2	251.50	16.02	17.57	19.40	19.40
11.	Roof drainage	m^2	428.70	7.32	8.05	8.98	8.98
12.	Roof cladding	m^2	428.70	28.82	31.20	34.70	34.70
13.	Screeds	m^2	2035.80	0.92	1.00	1.15	1.00
14.	Plasters	m^2	8610.90	4.07	4.44	4.92	4.44
15.	Interior tiling	m^2	1560.40	36.05	38.70	45.02	38.70
16.	Metal fixtures	kg	4755.40	3.08	3.35	3.90	3.35
17.	Painting	m^2	8602.80	1.35	1.45	1.67	1.45
18.	Flooring	m^2	2268.30	50.03	54.00	64.03	54.00
19.	Windows & external doors	m^2	191.20	237.21	258.99	294.01	284.75
20.	Internal doors	m^2	206.00	54.88	59.89	69.08	59.89
21.	Façade plasters	m^2	913.90	32.36	35.58	41.05	35.58
22.	Façade cladding	m^2	268.60	38.38	40.99	47.95	40.99
23.	Heat source	szt	1.00	60090.00	65959.00	77179.30	65959.00
24.	Heating system	m^2 UFA	1716.00	15.08	16.14	18.63	16.14
25.	Disposal system	m^2 UFA	1716.00	7.22	7.67	8.77	7.67
26.	Water system	m^2 UFA	1716.00	11.83	12.61	14.26	12.61
27.	Ventilation	m^2 UFA	1716.00	22.13	23.82	26.65	23.82
28.	Electrical	m^2 UFA	1716.00	23.49	25.48	29.96	25.48
29.	Communication	m^2 UFA	1716.00	17.82	19.27	21.57	19.27
30.	Lifts	pcs.	1.00	30037.00	31965.00	36191.10	31965.00

- The contractor can accurately schedule the work and assess costs prior to tender, and no major changes to the schedule are to be expected. In this model, risks and uncertainties are allowed for only in the form of cost allowances arbitrarily spread over the items of the schedule of payment and included in kj rates;
- The model does not provide any measure of the probability of winning the job. Instead, it focuses on defining a "reasonable price" corresponding to the perceived desirability of the work;
- The bid/no bid threshold of the contract attractiveness was set arbitrarily.
- The contract desirability remains in the linear relationship to the bid price (as in Fig. 1). This relationship was intuitively assumed by the authors and is not supported by hard evidence.

Further research, including contractor opinion surveys, is planned to support these assumptions.

Conclusions

Decisions whether to bid and what price to offer directly affect the economic efficiency of a contractor. They should not be based solely on intuition and experience. To avoid losses, the potential bidder should analyse acceptable solutions by means of reliable methods and using credible input. The approach proposed in the paper may facilitate establishing the contractor's in-house procedures and managerial decision support systems for pricing process. It enables the estimators to consider many factors (some of them of purely qualitative character) that affect both the chance of winning a contract and capacities to deliver and satisfy the client. However, the presented approach for modelling bidding decisions is a concept and needs validation.

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Research issues undertaken within quality management – the overview of selected literature

Anna M. Olszewska

ABSTRACT

Quality is currently a key element in the process of the rivalry where the customer is at stake. Contemporary enterprises undertake several actions aimed at its creation and more effective quality management. This is as well required by the market with enterprises of various character that frequently demand specific solutions. The scientific environment eagerly develops this concept in response to such a prevailing need.

The issue of quality management, despite its long history, remains a dynamically developing research discipline and a scientific consideration. Subsequently, this is a very extensive field which encompasses many issues. Thus, this work mainly focuses on identifying research threads undertaken within quality management in selected periodicals. The article describes the undertaken overview and indicates research threads entailed within the analysed subject matter. Moreover, the resultant list of threads was presented in the form of a knowledge map reflecting their coexistence in specific articles. The methods used while preparing this article constitute an overview of the literature and a network analysis.

The research threads highlighted in the paper indicate, which topics are of interest among researchers in terms of issues related to quality management, while their presentation in the form of a network enables fast and unambiguous access to knowledge within this area. The results of analyses described in the publication may attract the interest of mainly those who scientifically deal with the development of the concept of quality management, as well as enterprises that would wish to get acquainted with current trends in this field.

KEY WORDS

quality, quality management, research issues, knowledge map

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Introduction

The concept "quality" does not have one, unambiguous definition (Gudanowska, 2010; Urban, 2007). This idea has been accompanying humans since the beginning of our existence. Egyptians, Greeks, Romans, andother ancient civilisations considered quality as a symbol of perfection (Elshennawy, 2004). Later, as the society developed, the concept also evolved. As an example, Juran defined it as "fitness for use" (Liepina et al., 2013), Dale, Van der Wiele and Van Iwaarden as "fitness for purpose" (Liepina et al., 2013) again Crosby "as conformance to requirements, not as goodness" (Johnson, 2001). The nowadays meaning is created differently, based on a field of study or business it applies to (Szczepańska, 2013). The sense would vary among managers, medical doc-

tors, and philosophers (Urban, Czerska, 2016). The diversity of definitions of quality transfers to the disparate perception of its management. Liepiņa, Lapiņa, Mazais define Quality Management (QM) as "the process whereby certain operations are performed to ensure the achievement of the objectives and improve the company performance" (Liepina et al., 2013). It is intimated, that this process is made of successive, locked in the cycle of activities, which include: (1) quality planning, (2) quality control, (3) quality assurance, and (4) quality improvement (Standard ISO 9000). Over the years, along with the evolution of the concept of quality and quality management, research threads related to QM have been changing. The changes concerned the number of publications linked to both the quality management and fields, considered in the context of the described issue. In the first part of the publication, the Author described how had the quantity of the publications changed over the last 25 years. Firstly, the overall number of publications was analysed and then it was checked for areas that were developing. In the second part, a detailed analysis was conducted of the term "quality management" that coexisted with other expressions and ideas in 2014–2015 and in the most of 2016. The results were presented with the help of the tool VOSviewer. This software visualises the connections and relations between multi-element data sets. Created maps may take different forms, highlighting different aspects of presented information (Gudanowska, 2015). In this article, the form of the network visualisation has been chosen.

1. Preliminary analysis

As the first step of the analysis, information was collected concerning the quantity of publications referring to quality management in 1997–2016. The Author used two databases: the Web of Science and Scopus. Results have been organised into four types of papers: article, conference paper, book, and a book chapter. The breakdown of the number of publications is presented in Figure 1.

Figure 1 shows that the number of publications related to the notion "quality management" is different in both databases. Significantly more publications were collected in Scopus, compared to the Web of Science. That is also why the Author mostly focused on the further considerations, on the data from a more comprehensive database, i.e. Scopus.

Looking at Figure 1, it is noticeable that for a long period (1995–2005) the number of publications mostly maintained stable at about 1200–1400 publications per year. Since 2006, a significantly increasing interest in the aspect is to be noted, stopping in 2009, at the level of nearly 4000 publications in that year. It was followed by a clear decrease in interest over the year. However, after a few years, in 2013, the number of publications started to increase again, with its peak in the year 2014. The year 2015 came with another minor decrease in the interest in the problem of quality management. A further downturn occurred in 2016 and should not be taken into consideration because the presented data do not incorporate the

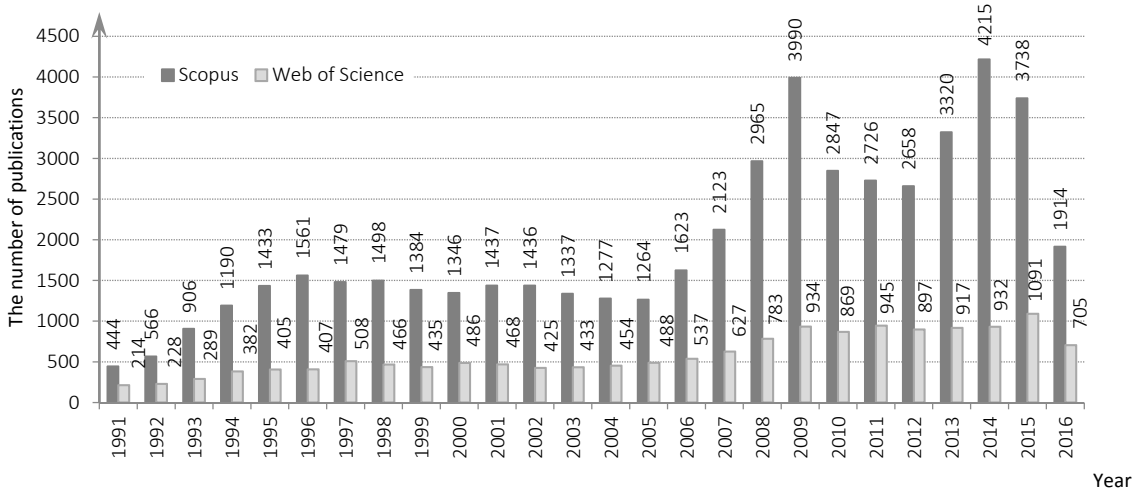

Fig. 1. Number of publications connected with the notion of 'Quality Management' from databases Web of Science and Scopus

Source: author's elaboration based on (https://bazy.pb.edu.pl, 27.11.2016).

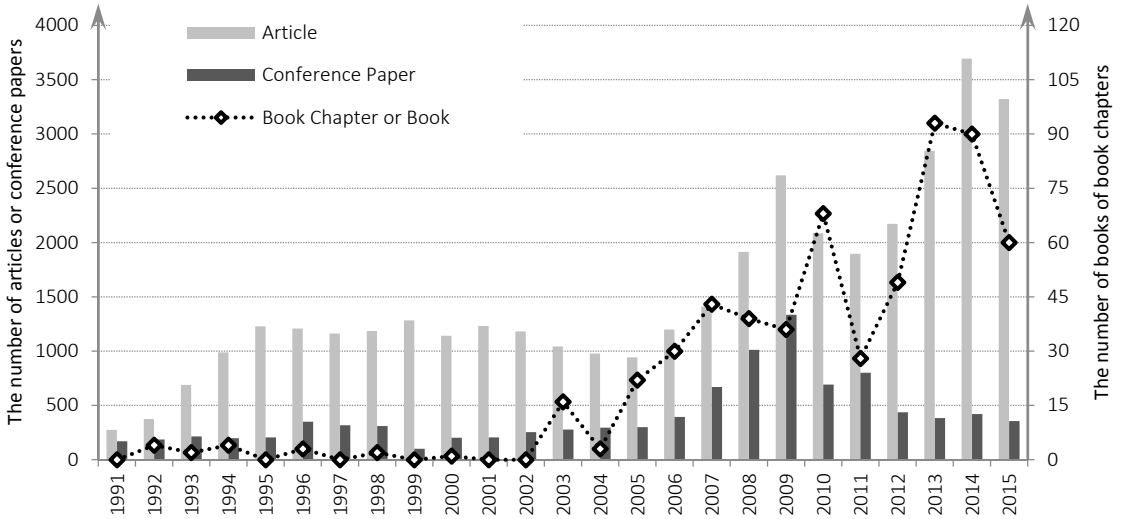

Fig. 2. Number of articles, conference papers, and book chapters or books connected with the notion "Quality Management" from the database Scopus

Source: author's elaboration based on (https://bazy.pb.edu.pl, 27.11.2016).

whole unit of time, as the analysis was conducted based on the data from 27 November 2016.This is the reason behind the exclusion of the year 2016 from further descriptions of this chapter.

The interesting aspect of the presented structure seems to be a specification regarding the type of publication that becomes dominant regarding the term "quality management". The comparison of the number of certain types of publication has been shown in Figure 2.

While analysing Figure 2, it is noticeable, that previously mentioned the significant jump in the interest in quality management in 2006 is also reflected in the articles, as in conference papers. However, after the year 2009, in the case of the latter, a gradual decrease is observable. It can be concluded that after that year, the topic of quality management stopped being a popular issue discussed at conferences, plateauing in 2012 at about 300–400 publications per year. Nonetheless, in the case of articles, books, and book chapters, the interest in quality management, despite the initial decline after the year 2009, experienced an increase in years 2013–2014. After this period, a minor decrease of the above-mentioned papers is noticeable. To identify the source of several changes in the number of publications related to quality management, the investigation of the fields that used the term quality management was made in the next step. Two analyses were concluded in relation to this criterion, the first of which involved creating a diagram (Figure 3), in which the prevalence of the notion of "quality management" in certain fields of knowledge was expressed through the size of text.

Fig. 3. Fields of publications related to the notion "Quality Management" from the database Scopus

Source: author's elaboration based on (https://bazy.pb.edu.pl, 27.11.2016).

By analysing Figure 3, it can be concluded that the term has been mainly appearing in publications related to the field of Medicine during the analysed period. Significantly less frequently but still somewhat often, it appeared in the field of Engineering. The other areas, in which issues connected with quality management have been described were Business, Management and Accounting, Computer Science,

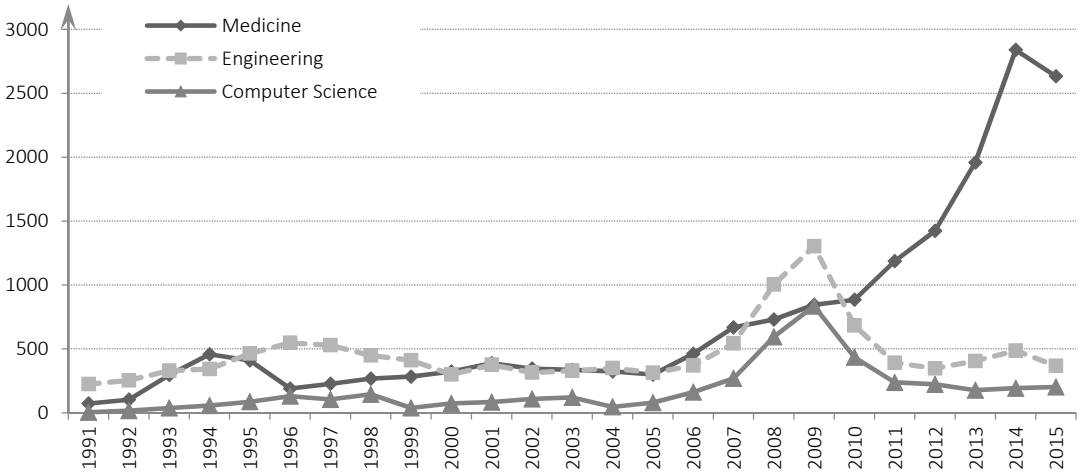

Fig. 4. Number of publications connected with the notion "Quality Management" in areas of Medicine, Engineering and Computer Science from the database Scopus

Source: author's elaboration based on (https://bazy.pb.edu.pl, 27.11.2016).

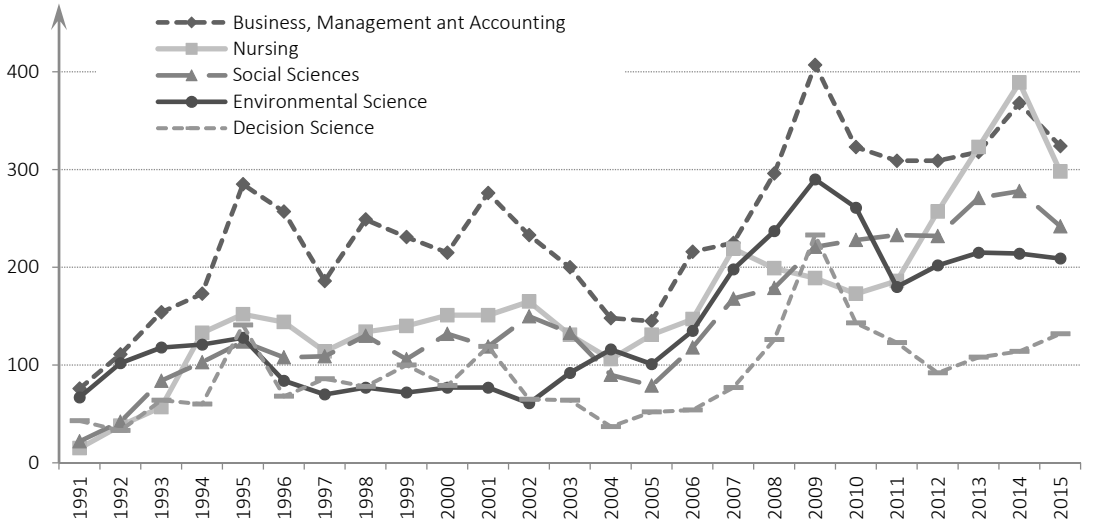

Fig. 5. Number of publications connected with the notion "Quality Management" in areas of Business, Management and Accounting, Nursing, Social Sciences and Environmental Science from the database Scopus

Source: author's elaboration based on (https://bazy.pb.edu.pl, 27.11.2016).

Nursing, Social Sciences, Environmental Science and Decision Science. The remaining fields occurred much less frequently.

Chosen and mentioned above fields, i.e. those, in which publications related to quality management appeared most frequently, have been analysed for changes in the number of publications in the following years. The goal of this analysis was to show areas, on which the subject of quality management was mainly focused during the analysed period. Changes in the number of publications related to quality management and connected with the fields mentioned above in1991–2015 were presented in the graphs in Figures 4 and 5.

While analysing Figures 4 and 5, it is noticeable, that issues related to quality management, described in publications from the fields of Medicine and Nursing indicate the clear upward trend appearing in 2005–2014, which significantly increased in 2011. Only in 2015, the number of publications connected with the described term from the areas of Medicine and Nursing has slightly decreased. The situation looks similar when it comes to the field of Social Sciences; however, in this case, it is noticeable that the

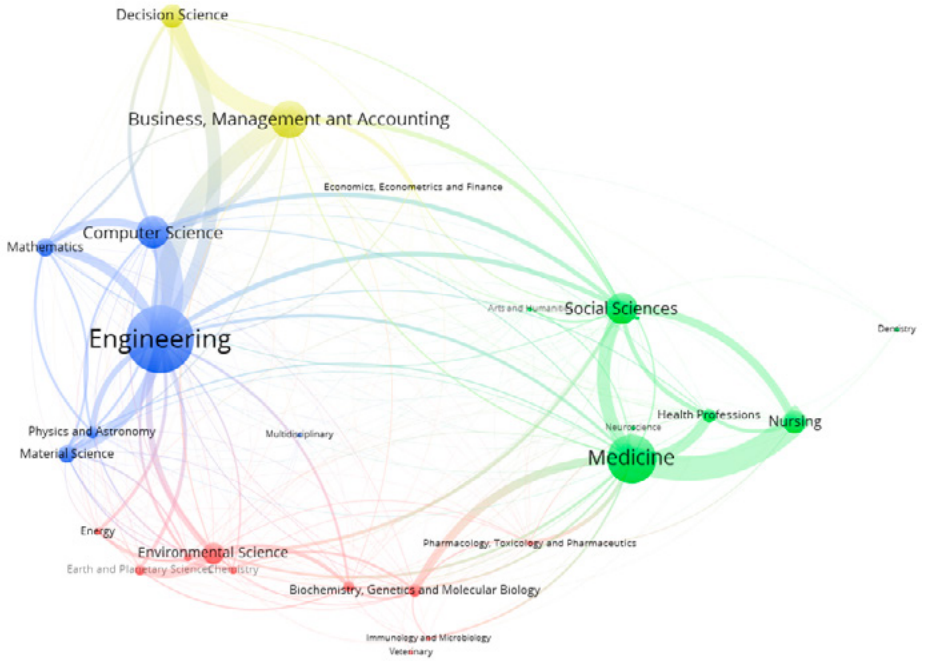

Fig. 6. Map presenting the co-occurrence of areas connected with publications related to the scope of quality management in 1991–2016

Source: author's elaboration based on (https://bazy.pb.edu.pl, 27.11.2016) using VOSviewer.

increase is more rapid at the beginning, and slowing faster at the end. When it comes to the fields of Engineering, Computer Science, and Decision Science, a significant jump in the interest in the issues of quality management was noted in 2009. After that, the number of publications decreased sharply. A similar peak can also be observed in the area of Environmental Science; however, here since the year 2011, the number of publications related to quality management has practically remained static. It should also be noted that the subject of quality management was still present, despite temporary decreases in areas of Business, Management and Accounting.

Summarising the above, it is worth mentioning that the issue of quality management, despite the fact of it not being a trend anymore, differently than in 2009, is still current in many fields. In areas related to Medicine, it has been particularly popular; however, it is still classically developing in fields connected with Engineering, Computer Science, and Environmental Science.

Consequently, it should be interesting to investigate how the number of publications related to quality management has formed in certain areas. The map of the connections between areas, made with the help of the VOSviewer program, is presented in Figure 6.

The map of the connections between the areas, in which the articles, conference papers, books or book chapters related to quality management were pub-

Tab. 1. Clusters of areas connected with publications related to the scope of quality management in 1991–2016

Clusters	Areas
Cluster 1	– Environmental Science – Agricultural and Biological Sciences – Biochemistry, Genetics and Molecular Biology – Earth and Planetary Sciences – Pharmacology, Toxicology and Pharmaceutics – Chemistry – Chemical Engineering – Energy – Immunology and Microbiology – Veterinary
Cluster 2	– Medicine – Nursing – Social Sciences – Health Professions – Psychology – Arts and Humanities – Neuroscience – Dentistry
Cluster 3	– Engineering – Computer Science – Material Science – Mathematics – Physics and Astronomy – Multidisciplinary
Cluster 4	– Business, Management and Accounting – Decision Science – Economics, Econometrics and Finance

Source: author's elaboration based on (https://bazy.pb.edu.pl, 27.11.2016).

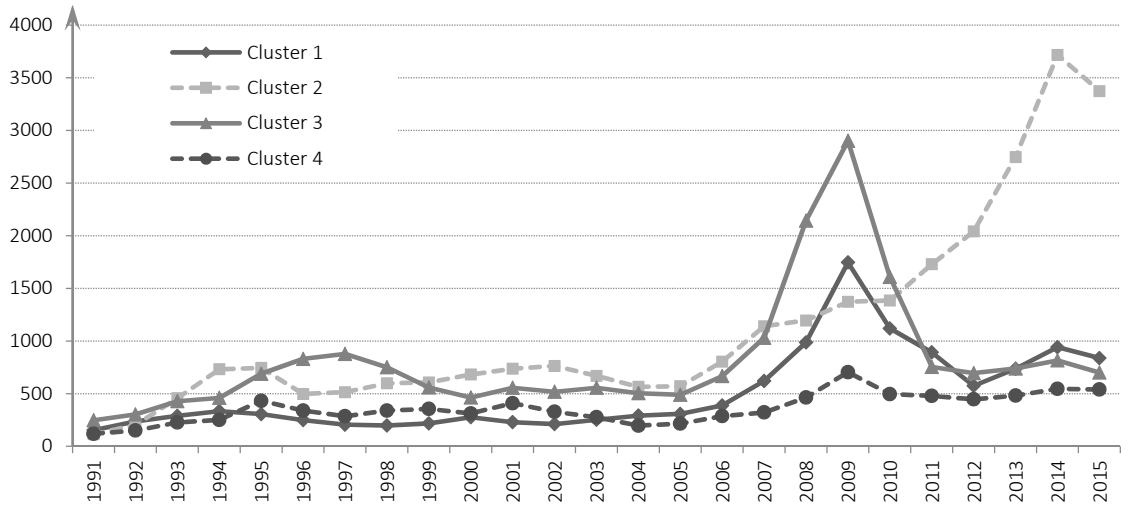

Fig. 7. Number of publications connected with the notion "Quality Management" from the database Scopus grouped into clusters
Source: author's elaboration based on (https://bazy.pb.edu.pl, 27.11.2016).

lished is presented in Figure 6. It indicates the existence of many links between the fields. The strongest connections are between areas, such as Engineering, Computer Science, the area of Business, Management and Accounting and Decision Science, but also between Medicine, Nursing and Social Science.

The construction of the dependents map also allows to point out the clusters of areas appearing most frequently in publications related to quality management. The compartmentalisation into clusters can be observed in Figure 6 (highlighted in different colours) as well as in Table 1.

The analysis of the co-existence of areas, in which issues of quality management have been discussed, indicated the presence of four clusters. The first of them involved fields such as Environmental Science, Agricultural and Biological Sciences, Biochemistry, Genetics and Molecular Biology as well as many others. The second cluster concerned mainly the areas of Medicine, Nursing, Social Sciences, and Health Professions. The third one referred primarily to the areas of Engineering, Computer Science Material Science, and Mathematics. Finally, the last cluster included the fields of Business, Management and Accounting, Decision Science and Economics, Econometrics and Finance.

The resulting division will serve as the basis for further analysis of changes in the number of publications related to quality management during the considered period. Figure 7 presents the view of the number of publications per all clusters.

While analysing the changes of the total number of publications from areas of certain clusters, it should be mentioned that those related to quality defined in the context of the environment (Cluster 1) gained the highest amount in 2009. After that time, the interest in the described aspect has decreased and remained at a plateau over the last couple of years at about 800–900 publications per year. It should also be noted that this particular cluster has shown over a fivefold increase in the number of publications from the scope of quality management during the considered period, which gives us an average growth rate of about 7% per year. A similar situation took place in the case of Cluster 3, which relates to Engineering in the broad sense. However, while analysing the course of changes in the number of publications from this cluster, two temporal increases should be underlined. The first occurred in 1995–1998 (the result of the increase in the number of publications in the area of Material Science), and the second – in 2007–2010, which was related to a peculiar trend of quality management. Since 2011, the number of publications in this cluster has reached a plateau of about 700–800 publications per year. Considering the classical association of quality management with engineering and related areas (e.g. Material Science, Computer Science), this cluster had the highest number of publications in comparison with other clusters from the beginning of the considered period, and that is also the reason behind the lowest increase. It was nearly threefold, which gives an average growth rate of about 4% per year. Over a fourfold increase in the number of publications was observed in the case of Cluster 4, which involves issues of quality management connected with Management and Economy. The average growth rate, in this case, was over 6% per year. The number of this type of publications seemed to be nearly systematically and con-

stantly increasing, with temporary accelerations (e.g. in 2009). The highest – almost a thirtyfold – increase in the number of publications related to quality management was noticed in Cluster 2, which is connected with the fields of Medicine and Human Health. During the considered period, this cluster gained the average growth rate of 15% per year.

aspects of the healing process. The second cluster (green colour) is also connected with Medicine, but this time, in the context of quality of the organisation of work in the hospital and attitudes promoted among employees. The last third group of publications was related to the classically understood company quality management, which contains mainly the terms

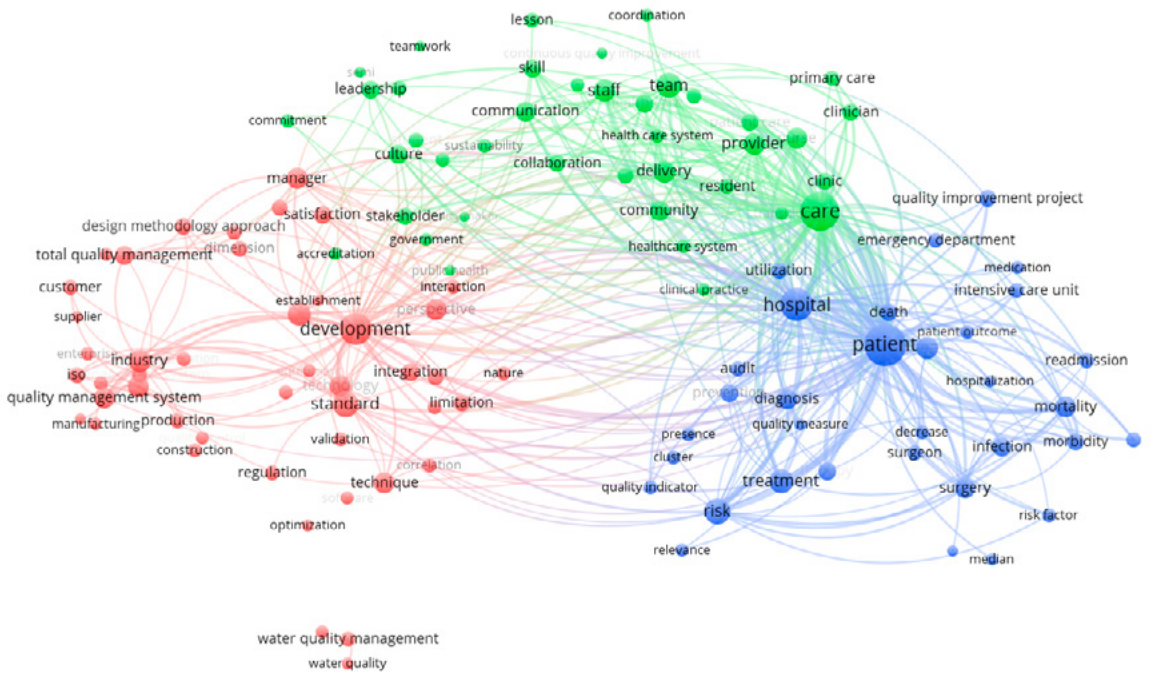

Fig. 8. Map representing the co-occurrence of terms characterising analysed articles related to the scope of quality management in 2014

Source: author's elaboration based on (https://bazy.pb.edu.pl, 27.11.2016).

3. Enhanced analysis

The next step of conducting the analysis was a process of making maps representing the co-existence of issues covered together with quality management over the last two years and partly 2016.The analysed material also included titles, summaries, and keywords found in the database Scopus. The resulting dataset was reduced by choosing only those terms that appeared for at least 40 times and by eliminating expressions characteristic for every publication, such as purpose, trends, theory, and scope. The created map of the year 2014 is presented in Figure 8.

Figure 8 highlights three primary groups of terms, which have appeared in publications related to quality management. The first cluster (blue colour) contains terms related to the process of treatment, including, for example, opinions of patients, evaluation of their stay in the hospital, qualities of different related to the production process. It includes expressions connected to standards, development, the perspective of a client and supplier, product design or innovations. This group also contains classified elements related to quality in the context of Environment (water quality).

The next co-occurrence map was created using the data of 2015 (Fig. 9). It also indicates the existence of three groups of publications related to the term "quality management". One of them, similarly to this in 2014, was created using the publications connecting that term with Healthcare and related risks. The next group included expressions related to the quality of actions undertaken in hospitals. They cover, for example, actions linked with education and training for personnel as well as team management. There also appeared aspects connected with documentation and equipment used. The last cluster referred to publications related to quality management in the case of different companies. However, in that year, they were

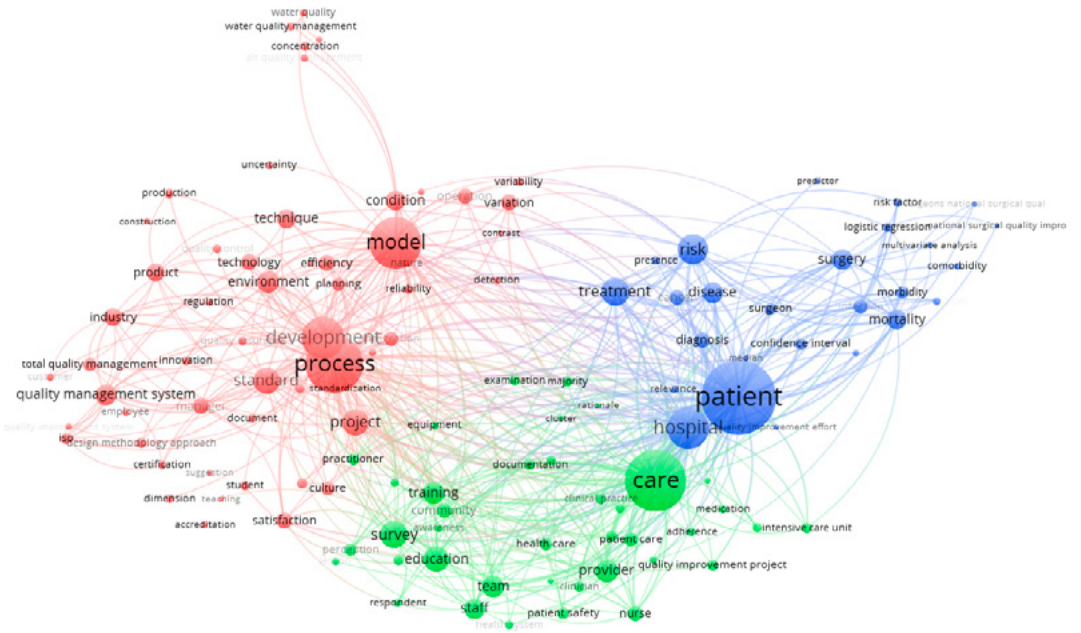

Fig. 9. Map representing the co-occurrence of terms characterising the analysed articles related to the scope of quality management in 2015

Source: author's elaboration based on (https://bazy.pb.edu.pl, 27.11.2016).

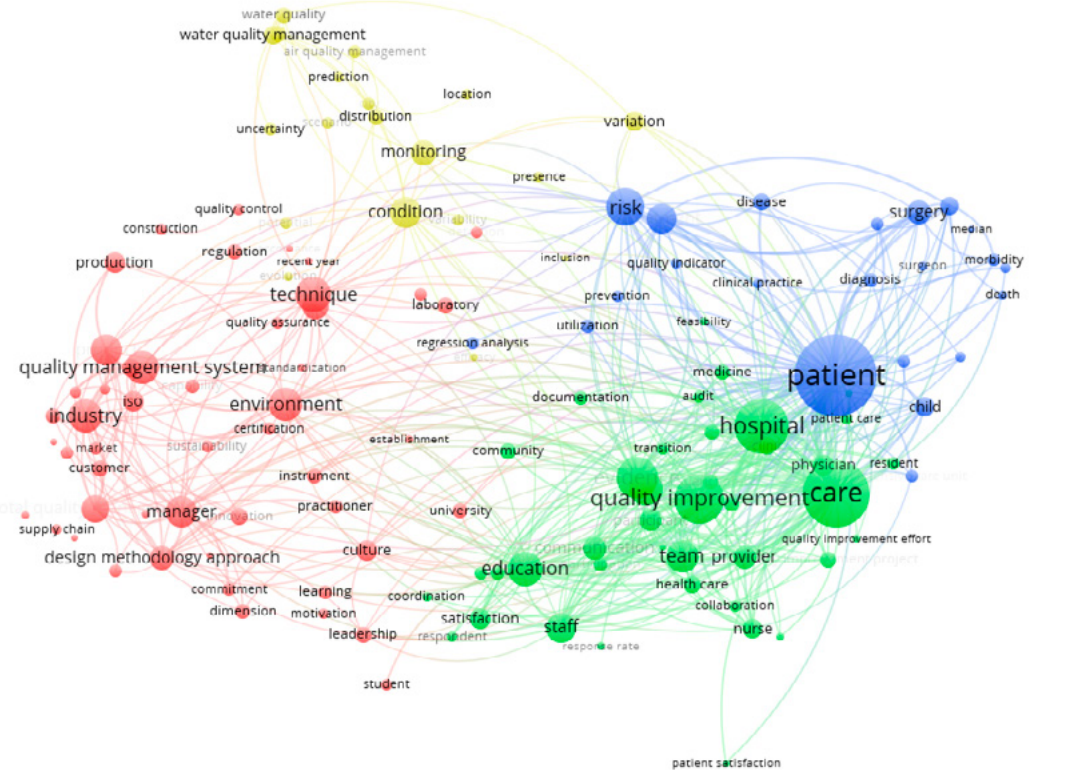

Fig. 10. Map presenting the co-occurrence of terms characterising analysed articles related to the scope of quality management in 2016

Source: author's elaboration based on (https://bazy.pb.edu.pl, 27.11.2016).

mainly combined with concepts of process, project or modelling. Apart from those, such expressions as development, planning, client satisfaction or standardisation were found.

Over the analysed part of 2016, there were much fewer publications than after the previous year, and that is why expressions were chosen that appeared at least 20 times. After, they were excluded if characteristic for all documents, just like in the previous years. The resulting map was presented in Figure 10. It demonstrates that publications related to quality management grouped into four clusters. The first one, similarly to two previous years, was concentrated on issues connected with Healthcare. The second one, also related to hospitals, included expressions referring to people management, with particular emphasis on their education or training, as well as communication. The next cluster covered quality management in the context of different companies, mainly production ones. The publications discussed issues related not only to quality management but also to the environment, standardisation or designing. Again, techniques and technology were widely described but, on the other hand, the organisational culture was another focus of attention. That year also saw one group of publications connected with issues of quality management linked to the protection of the environment (water and air).

Conclusions

Term "quality management" is a very broad concept. The above analysis indicates that for last 25 years, it has been developing in four different groups, described here as clusters, namely, (1) Environmental Science, Agricultural and Biological Sciences, Biochemistry, Genetics and Molecular Biology, and many more; (2) Medicine, Nursing, Social Sciences and Health Professions, etc.; (3) Engineering, Computer Science Material Science and Mathematics, and others; and (4) Business, Management and Accounting, Decision Science and Economics, and Econometrics and Finance. Changes in the number of publications in the clusters occurred differently; however, the analysis of their execution indicates the existence of certain publication trends. The issue of quality management for the most part (excluding Cluster 2) was the most popular in 2009. After that, the interest in the subject has significantly decreased. The exception was the cluster linked with Medicine. The highest publication popularity occurred in 2014. Overall, it is worth mentioning that despite some temporal drops, the number of publications related to quality management has significantly increased during the considered period. The increase ranged from several times (in the case of engineering cluster) to a few dozens (in the case of medicine cluster) of times.

Apart from dynamics, the issues covered by certain clusters have also changed. For example, the analysis of expressions co-existence maps presented above. Therefore, in the cluster related to Medicine, two trends were noted during the considered period. The first was connected only to the process of healing and therapy; however, the second one concerned healthcare service providers. Also, in the case of the second one, the increase in the importance and interest in education and training of employees was noticed over the considered years. The remaining three clusters, despite references to publications from the scope of Medicine (especially in the case of the second trend), were linked mainly to analyses and researches related to the functioning of companies. In this group, changes in trends were also noticeable. Therefore, for example, in 2014, the attention to the context of quality management was drawn to the development and integration, while widely describing expressions related to standardisation and different types of limitations. In the next year, more focus was given to the context of the development or standardisation, processes, projects, and models. Moreover, the year 2016 focused on techniques and technologies. On the other, more attention was given to culture, leadership, and improvement of employees.

In summary, it should be stated that the issue of quality management is not only an important problem from the science perspective but also a very dynamic subject which is continuously and intensively developed by many researchers.

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